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OUTFITS FOR ABSORPTION SPECTROPHOTOMETRY

IN THE VISIBLE AND ULTRA-VIOLET REGIONS

ADAM HILGER, LTD.
24 ROCHESTER PLACE
CAMDEN ROAD
LONDON N.W.1

OCTOBER, 1931

SB
FRANKLIN INSTITUTE
PHILADELPHIA

OUTFITS *for* ABSORPTION SPECTROPHOTOMETRY

A GUIDE TO THE CHOICE OF SUITABLE SPECTROPHOTOMETRIC APPARATUS FOR:

(*a*) THE ULTRA-VIOLET REGION

For studying the relation between absorption and chemical constitution, the dissociation constants of inorganic and organic compounds and the effect of solvents on absorption spectra, for the identification and measurement of organic substances, for the study of biological substances (blood serum, cerebro-spinal fluid, vitamin D and other derivatives of ergosterol), etc.

(*b*) THE VISIBLE REGION

As required for identifying and measuring dyes, natural or artificial colouring matters of foodstuffs and other substances, etc.

WITH AN APPENDIX CONCERNING THE DETECTION BY SPECTRUM ANALYSIS OF METALS IN PLANT AND ANIMAL FIBRES AND OTHER ORGANIC SUBSTANCES

A description of the principles and methods of absorption spectrophotometry will be found in "The Practice of Absorption Spectrophotometry with Hilger Instruments," by F. Twyman, F.Inst.P., F.R.S. (Adam Hilger, Ltd.).

NOVEMBER 1931

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CONTENTS OF THIS BOOKLET.

PAGE
INTRODUCTION ... 5
  The Present Day Position of Absorption Spectrophotometry ... 6
  Photoelectric Cells in Absorption Spectrophotometry ... 6

PART ONE.

OUTFITS FOR ULTRA-VIOLET SPECTROPHOTOMETRY ... 7
  Choice of Spectrograph ... 7
  Choice of Tubes ... 7
Recommended Outfit ... 8
Additional Accessories ... 9
Specifications of Instruments ... 10
  Spectrograph ... 10
  Spekker Ultra-violet Photometer ... 11
  Absorption Tubes ... 15
  Light Source ... 16
  Apparatus for Examining and Measuring Spectrograms ... 18
  Photographic Plates ... 20

PART TWO.

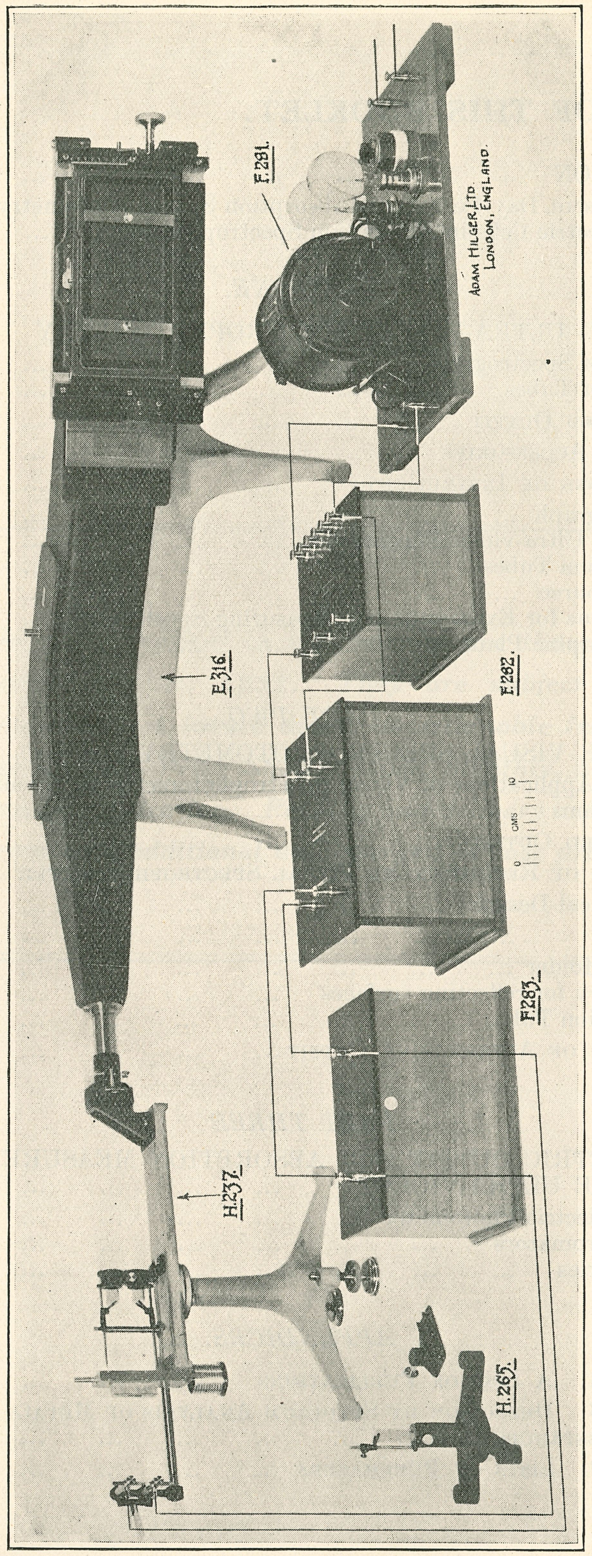
OUTFITS FOR VISUAL SPECTROPHOTOMETRY ... 21
  Recent Applications of Visual Spectrophotometry to Chemical Investigations ... 21
Recommended Outfits ... 22
Description of Recommended Visual Spectrophotometer ... 23
  Mechanical Design ... 24
Accessories ... 25
  Fabric Holder ... 26
  Accessory for reflecting surfaces ... 26
  Absorption Tubes ... 26
Description of Alternative Outfit ... 27

PART THREE.

PHOTO-ELECTRIC OUTFIT FOR ABSORPTION MEASUREMENTS IN THE ULTRA-VIOLET ... 28
  Photo-electric Photometer ... 28
  Monochromators ... 29
  Accessories ... 31

APPENDICES.

Appendix A. A List of Publications ... 32
Appendix B. Detection by Spectrum Analysis of Metals in Organic Substances ... 32
Appendix C. Lists of Purchasers ... 34



Spectrophotometric Outfit for the Ultra Violet. (See page 8.)

OUTFITS FOR ABSORPTION SPECTROPHOTOMETRY.

INTRODUCTION.

Kayser, writing in 1908 concerning ultra-violet absorption spectrophotometry, drew attention to the unsatisfactory nature of the work which had been and was then being done in this direction, owing to its being merely qualitative.* Not only the intensity, but the actual position of the maximum of an absorption band is undetermined until quantitative measurements of the absorption have been made, since variations throughout the spectrum of intensity of the light source, of sensitiveness of the photographic plate, or of dispersion, may cause the apparent maximum of absorption to be in a position different from that of the actual maximum. All absorption work, therefore, which is done other than quantitatively is subject to this criticism.

The passage in Kayser's *Handbuch der Spectroscopie* which is quoted in the footnote caused us to develop the sector photometer for ultra-violet spectrophotometry which, introduced by us about 1912, was the first quantitative ultra-violet spectrophotometer to be placed on the market.

With this instrument, in conjunction with the fixed adjustment quartz spectrographs introduced a few years earlier, most of the quantitative work in this region has been done ; and its reliability has been repeatedly proved in many ways and by many workers in our own laboratories and elsewhere.†

This instrument may perhaps be entirely superseded by the Spekker‡ Ultra-violet Spectrophotometer briefly described in the following pages,§ which is more convenient and speedy to set up and use than the earlier instrument, while giving more light and somewhat greater accuracy.

For the visible region instruments were available much earlier, yet even here spectrophotometry did not receive the attention it deserved in the chemical laboratory until quite recently. Yet it is only necessary to remember one or two instances of its application in order to remind oneself of the very great importance of this physical measurement. The classical investigations on CO in blood by Vogel, and on the separation of Neodymium and Praseodymium by Auer v. Welsbach, may be cited in this connection.

Measurements of absorption acquire their chief interest when plotted on a wavelength scale. With all the instruments described in this booklet the necessary readings for doing this are immediately at hand without the necessity of the purchaser carrying out laborious calibration himself.

The infra-red, in which region less work has been done, is also of interest for the chemist, and suitable instruments for the region up to 9 μ are described in

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* *Handbuch der Spectroscopie von H. Kayser*, Band 3, S. 49 : " Aber alle diese Methoden eignen sich doch nicht zu einer genauen Bestimmung der Absorptionsconstanten für viele Substanzen und verschiedene Wellenlängen. Trotz der zahlreichen im Vorhergehenden besprochenen Apparate, musste man bis vor Kurzem sagen, dass es kein brauchbares Instrument für Photometrie im Ultra-violett giebt mit dem man etwa daran hätte denken können, eine ausgedehnte Untersuchung z. B. organischer Substanzen vorzunehmen. Man war ausschliesslich auf die später zu besprechende Methode angewiesen, die namentlich von Hartley ausgebildet und durchgeführt ist, die aber keine Messung der Constanten, höchstens eine Schätzung über die Grösse der Absorption zulässt."

† See Twyman and Simeon *Trans. Opt. Soc.* XXXI., No. 4, 1929-30 ; pp. 174 and 175.

‡ Registered Trade Mark.

§ For full description see F. Twyman, *Trans. Opt. Soc.* Vol. 32. No. 1, 1930-31.

Section D of our catalogue. The closely allied "Raman Effect" is scarcely far enough advanced in its interest for chemists to be included here; instruments for its study will be found in Section E of our catalogue.

THE PRESENT DAY POSITION OF ABSORPTION SPECTROPHOTOMETRY.

Spectroscopy twenty-five years ago was, as far as chemists were concerned, the hobby of a very limited number; and the same remark applies with even greater force to spectrophotometry, which term as applied to absorption spectra indicates the determination of the absorption of a substance for each wavelength in the spectrum.* Its gradual acceptance as a physical method of value to the organic chemist is largely due to the visual and photographic instruments introduced by Adam Hilger, Ltd. from 1904 to 1911 and the successive improvements and accessories introduced by the firm since. These instruments, supplied fully adjusted and calibrated in wavelengths, tested in actual use and accompanied by printed instructions, relieve the purchaser from the labour of adjustment and calibration which were formerly such formidable obstacles to the investigator commencing work in this field.

The bibliography of recent work on *Absorption Spectrography* published by Adam Hilger, Ltd.† will show how important a part is now played by these instruments in very many branches of chemistry and technology.

In the following schedules of apparatus we include only equipments which we consider best for the various classes of work referred to; a variety of other instruments will be found in Sections D, E, and H of our catalogue.

PHOTO-ELECTRIC CELLS IN ABSORPTION SPECTROPHOTOMETRY.

Of recent years both photo-electric and selenium cells (with or without valve amplification) have been applied to spectrophotometry, and in appropriate instances increased sensitiveness of measurement is obtainable.

Such devices materially increase the complexity of the apparatus and of the technique. Furthermore, while bringing in fresh sources of error, they do not avoid errors arising from the optical apparatus to which they are adjuncts. Such errors are those of wave-length calibration, those due to stray energy, or imperfect alignment of apparatus and others resulting from the introduction of the sample into the beam. The use of a photo-electric cell in place of the eye or of a photographic record diminishes the likelihood of such errors being recognised, with the result that there is a liability that copious and apparently highly accurate results may be amassed which are actually unreliable. It is therefore to be recommended that the addition of the photo-electric cell arrangements, with their peculiar sources of errors and difficulties of technique, should only be resorted to by those who have made themselves perfectly familiar with the well-tried methods of spectrophotometry, the conditions for the successful use of which can be precisely and simply prescribed and assured.

For those who have acquired this familiarity we include an outfit which we recommend from the experience of our own laboratories (see page 28).

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* An account of the subject will be found in Nos. 26, 27, and 28 of "Chemistry and Industry" for 1930 under the title "Absorption Spectrography and some of its applications to Chemistry." The substance of these papers with much additional information is included in the book, "The Practice of Absorption Spectrophotometry." (Adam Hilger Ltd., price 3s. 6d. net, 3s. 8d. *post free.*)

† Free on application.

PART I.

OUTFIT FOR ULTRA-VIOLET SPECTROPHOTOMETRY.

CHOICE OF SPECTROGRAPH.

By far the most widely used spectrograph for this kind of work is the medium size Hilger Quartz Spectrograph, and it is this instrument in its latest form E 316 that we include in the recommended outfit on page 8. Cheaper instruments of the same size can be supplied (E 2, E 3) or a smaller size of spectrograph (E 31 or E 37). The disadvantages of the smaller instruments are that, having only one-third the dispersion of the larger size, they do not yield so high an accuracy of wavelength determination, and that for the same reason they are of limited application to spectrum analysis by emission spectra. The detection of the metallic constituents of plant and animal fibres and fluids, and other problems best solved by emission spectrography are very likely to arise from time to time in laboratories where absorption spectrography is carried out, and this in itself is a sufficient reason for selecting the larger instrument where funds permit it. Furthermore the increased dispersion has the advantage of giving a spectrum that can be examined successfully with a low power magnifier.

For some special classes of work it may be desirable to have the still larger quartz spectrograph E 383, (or the cheaper form E 1 of the same size) which has a dispersion three times that of the E 316. For instance, the spectrographic detection of minute quantities of aluminium in animal and vegetable substances has been undertaken by McCollum, Rask, and Becker (*Jnl. of Biological Chemistry*, May 1928, Vol. 77, page 753): Kahlenberg and Closs (*Science*, February 15th, 1929, Vol. LXIX, No. 1781): and S. Judd Lewis (*Jnl. Soc. Dyers and Colourists*, December, 1927, Vol. 43). In all these three cases Hilger quartz spectrographs were used, McCollum, Rask and Becker using the large quartz spectrograph, E 1 type, and Dr. Judd Lewis the medium size, E 3.

In order to ascertain which instrument to advise in connection with enquiries which we have received in this connection, we have compared the E 1 and E 3 spectrographs in the detection of one or two parts of aluminium per million in substances kindly supplied to us by the Rowett Research Institute. We have found that the E 1 is undoubtedly the easier instrument with which to perform this detection which, with the E 3, although possible, is difficult on account of the faintness of the lines of aluminium which are therefore liable to be masked by the proximity of other lines.

Particulars of these alternative instruments will be found by reference to page 11.

CHOICE OF TUBES FOR ABSORPTION SPECTROPHOTOMETRY IN THE ULTRA-VIOLET.

Heilbron, Kamm and Morton in measurements on the ultra-violet spectra of ergosterol and substances containing it (*Biochem. Journ.* XXI, No. 6, 1927), used liquid thicknesses of from 0.1 mm. up to several millimetres. For such work and for the examination of body fluids (absorption spectra of serum proteins, etc.) thicknesses up to 5 mm. are ample. For these the adjustable micrometer cell H 206 is useful, and has been used by Dr. F. Campbell Smith for body fluids—*Proc. Roy. Soc. B.*, Vol. 106, 1930, p. 292.

Suitable lengths of cell to have available for general absorption work on liquids in the ultra-violet are 1 cm. and 2 cm.; a pair of each, with one of the micrometer cells, will cover all ordinary requirements.

These then are the tubes included in the recommended outfit on page 8.

RECOMMENDED OUTFIT FOR ULTRA-VIOLET SPECTROPHOTOMETRY.

COMPRISING EVERYTHING NECESSARY FOR QUANTITATIVE SPECTROPHOTOMETRY IN THE ULTRA-VIOLET.

With this outfit, using panchromatic plates, measurements may be extended throughout the visible spectrum. The accuracy obtained in the visible region is, however, considerably less than that obtained by the visual outfit described later, partly because the dispersion of the quartz spectrograph is small in that region, and partly because the method of photographic spectrophotometry does not equal in accuracy the direct use of the eye.

In this outfit will be found everything necessary for carrying out investigations in ultra-violet spectrophotometry. No essentials have been omitted except purely photographic dark-room equipment.

Catalogue No.	For details see Page.	Price
SPECTROGRAPH.		
* E 316.—**Quartz Spectrograph** with wavelength scale	10-11	£235 0 0
PHOTOMETER.		
H 237.—**Hilger Spekker† Ultra-Violet Photometer** complete with spark holder, electrodes and adapter to fit E 316 or E 3 spectrograph ...	11-14	75 0 0
TUBES FOR LIQUIDS.		
H 261.—**Two Mounts for Capless Tubes**	15	4 0 0
H 264.—**Two Pairs of Quartz End Plates**	15	1 10 0
H 252.—**Two Separating Rings,** 5 mm.	15	1 14 0
H 253.— ,, ,, ,, 10 ,, ...	15	1 14 0
H 254.— ,, ,, ,, 20 ,, ...	15	1 14 0
H 265.—**One Filling Stand for Tubes**	15	2 0 0
H 260.—**Micrometer Adjustable Tube,** reading from 0 to 5 mm. thickness of liquid stratum, with quickly detachable mount	16	17 0 0
ELECTRODES AND OUTFIT FOR SPARK.		
F 281.—¼ **k.w. Rotary Converter,** 110 volts or 220 volts D.C.; giving respectively 75 volts or 150 volts, 60 cycles, A.C.	17	26 0 0
F 282.—¼ **k.w. Transformer,** specially wound for spectrum work, including auto-transformer to give 8,000, 10,000, 12,500 or 15,000 volts	16	20 0 0
F 283.—¼ **k.w. Condenser,** of capacity suitable for above set	16	9 0 0
APPARATUS FOR EXAMINING SPECTRA.		
F 644.—**Negative Viewing Stand**	18-19	1 18 6
H 245.—**Eyepiece for Viewing Spectra** (like H 217, but without scale)	19-20	1 19 0
PHOTOGRAPHIC PLATES.		
F 144.—**6 doz. Wellington Anti-screen Plates,** 10″ × 4″	20	2 17 0
		£401 6 6

Where alternating current is available the Converter F 281 is not required.

Please Note.—When ordering any of the above instruments, the following information is required:

(*a*) Full particulars of the electrical supply to be used.
(*b*) The type of spectrograph with which the photometer is to be used (when a complete outfit is not being ordered).

For additional accessories see next page.

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*For cheaper instruments see page 11. †Registered Trade Mark.

ADDITIONAL ACCESSORIES FOR ULTRA-VIOLET SPECTROPHOTOMETRY.

FOR PRELIMINARY EXAMINATION OF ABSORBING FLUIDS.

It is often convenient before taking accurate measurements of absorption spectra with the spectrophotometer to make a preliminary qualitative examination. The following cells are useful for this purpose.

F 18.—**Adjustable Absorption Tube** (see *Baly's Spectroscopy,* Edn. 1, page 414) with scale in millimeters (not suitable for alcohol or ether)...	£2 2 0
F 115.—**Baly Tubes of Special Form** to stand most solvents (except those attacking rubber)	£2 12 0

For Baly Tubes of Fused Silica with and without micrometer adjustment see separate leaflet.

F 333.—**Fused Silica Cell for Absorption Experiments.** For rapid examination of the absorption of liquids in the ultra-violet; thickness of liquid about 6 mm.; thickness of cell wall about 1½ mm. Of clear fused silica, not optically worked	£0 17 6

For further details and for carriers, see Catalogue Section F, pages F 1, 2, 3, 4.

CONTINUOUS ULTRA-VIOLET LIGHT SOURCE.*

(*See pages* 17-18)

	Price in Gt. Britain.	Price Abroad.
F 656.—**Type I Hydrogen Vacuum Tube** (filled) ...	*Prices under revision*	
or F 657.—**Type II Hydrogen Vacuum Tube** (unfilled)		
F 658.—**2 K.V.A. Transformer** for exciting the above tubes. Input 110 v. (or 220 v.) single phase alternating current. Output 4000 volts with a current of 0.5 amps. Frequency 50 Herz.		
F 659.—**Regulating Sliding Resistance** 9 amp. 11 ohm.		

Please state voltage of electric circuit, when ordering.

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*Since this light source is not, even approximately, a "point" source, special care in alignment is necessary in its use.

SPECIFICATIONS OF THE ITEMS IN THE FOREGOING EQUIPMENT.

ALL METAL MEDIUM QUARTZ SPECTROGRAPH, E 316 and E 315

These spectrographs, with quartz prisms and lenses, have been very carefully designed with the following objects in view :

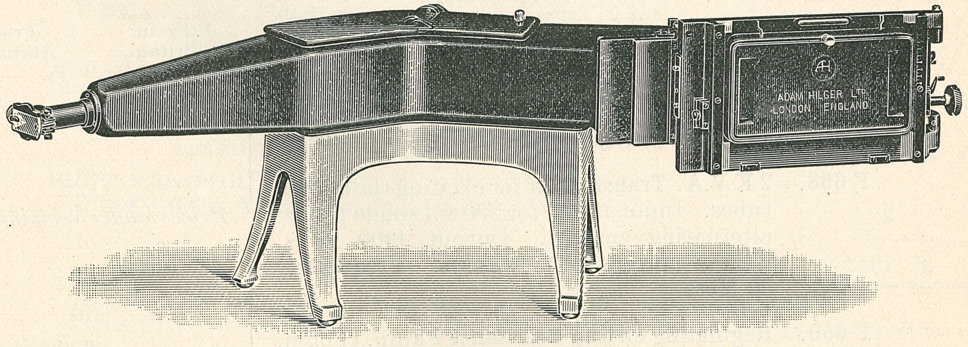
1. *To be in permanent adjustment.*
2. *To give the whole spectrum from* 10,000 A *to* 2,000 A *on one plate* 10″ × 4″.
3. *To give good definition over the whole spectrum on the ordinary photographic plate.*
4. *To give as large an amount of light as is consistent with the above conditions, thus enabling spectrograms to be taken with relatively short exposures.*

They are sent out completely adjusted, ready for photographs to be taken.

There is a slight curvature of the plate in the medium quartz spectrographs. On this account photographic plates for use on these instruments should be on thin glass and so ordered from the makers or us (see Section F of General Catalogue, page 20 of this booklet).

These spectrographs are constructed of metal throughout, including the plate-holder. The optical system includes lenses with aspherical surfaces so designed and corrected by the Hilger Interferometer process* that the instrument has extremely fine definition as well as great speed. The improvements over former models make these instruments peculiarly valuable in those cases where a short exposure is necessitated.

The dispersing system consists of one quartz Cornu prism. The lenses are 51mm. in diameter, with a focal length of 610 mm. (24 ins.). The spectrum is about 240 mm. long, and is photographed on one plate 10 × 4 ins.,† in whose height a number of spectra can be taken. For this purpose a rack and pinion motion is provided for raising or lowering the plate-holder. The slit (Hilger Cat. No. F 31) is provided with a diaphragm for varying its length (from 15 mm.) and one with three apertures enabling three comparison spectra to be taken in close juxtaposition without moving the plate.



E 316. Quartz Spectrograph.

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* British Patent 103,832/16 and corresponding Foreign Patents.

† When desired a plate holder for plates 9 × 24 cms. can be supplied in place of that for 10 ins. × 4 ins. In some countries the former size of plates is more easily obtained than the latter.

Model E 316 is fitted with a scale of wavelengths so mounted internally that it may be printed on the plate and developed up with the spectrum. The approximate accuracy of reading is

Wavelength.	Error of Reading.	Wavelength.	Error of Reading.
7000 A	100 A	2500 A	2 A
4000	20	2200	1
3000	5		

LIST OF MODELS OF MEDIUM QUARTZ SPECTROGRAPHS.

E 316.—All-Metal Medium Quartz Spectrograph with internal wavelength scale	£235	0	0
E 315.—All-Metal Medium Quartz Spectrograph without wavelength scale	£202	0	0

10″ × 1¼″ plate holders can be supplied instead of 10″ × 4″ without extra cost, and are recommended where for emission spectra the most critical definition is required over the whole length of spectrum simultaneously, the 10″ × 1¼″ plates being bent in the metal dark slide into the exact shape of the focal curve. We strongly recommend the 10″ × 1¼″ dark slide for metallurgical and mineralogical work though it is not necessary or suitable for absorption work. Owing to the difference in curvature of the plates the scale provided with E 316 does not give accurate readings with this dark slide. For the specially thin plates that must be used see page F 41.

E 386.—Additional Plateholder for plates 10″ × 1¼″, for E 316, E 315 spectrographs	£12	10	0

LESS EXPENSIVE AND OTHER SPECTROGRAPHS.

The less expensive Quartz Spectrographs, E 2 and E 3, also give excellent results and indeed have been more widely used than the more recent All-Metal Spectrograph E 316. They differ only in that their cameras are constructed of mahogany, and their optical systems, although of very great efficiency, do not represent such an advanced state of optical design as the foregoing, are available and may be substituted.

E 3.—Medium Quartz Spectrograph, with internal wavelength scale	£173	5	0
E 2.—Medium Quartz Spectrograph, without wavelength scale	£138	12	0

The small quartz spectrograph with wavelength scale, E 37 (£53 0s. 0d.) or the E 31 (of the same size but without wavelength scale, £35 0s. 0d.) has also been much used for absorption spectrography, and may often be substituted for the E 316 (but see note under "Choice of Spectrograph," page 7.)

The Large and Small Quartz Spectrographs will be found fully described in our Catalogue, Section E.

THE SPEKKER* ULTRA-VIOLET SPECTROPHOTOMETER, H. 237.

(For full description see the *Trans. Opt. Soc.* Vol. 32, No. 1, 1931.)

The instrument has been so designed as to be at once simple in construction, easy to set up, accurate and rapid in use. These factors should render it of special interest to chemists and others whose need is the rapid attainment of accurate results with a minimum of technical difficulty.

The basic principle of accurate ultra-violet spectrophotometry involves a device by which light from a single source is divided into two beams of which the one is reduced in intensity by known amounts, the other being selectively absorbed by the substance under investigation. This, which is usually known as the photometer, is used in conjunction with a quartz spectrograph to resolve both beams into spectra, a series of spectra taken with successive reductions of the variable beam being inspected for the positions at which the absorbed and the reduced spectra are of equal intensity, whence a curve can be drawn relating wavelength with absorption. For an example of this see the photograph, Plate I., and its corresponding curve Fig. H 237a.

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* Registered Trade Mark.

In various types of instrument different means are adopted for reducing the intensity of the comparison beam ; in some the duration of intermittent exposures is varied (The Hilger-Twyman Sector Photometer, the earliest instrument manufactured for quantitative absorption measurements and that with which most modern work has been done) ; in others, polarisation has been used and in others various methods of varying the aperture of the light-path are employed.* The present instrument is of the last named type. The light from the source is divided into two paths by a suitable arrangement of prisms. Each path contains an aperture, one being fixed, the other one variable, either by a shutter mechanism operated by a fine screw, or by interposing one of a carefully graded series of apertures cut in the circumference of a disc. The light paths are brought into close juxtaposition on the slit of a quartz spectrograph by means of rhombs. All the optical parts are made of quartz.

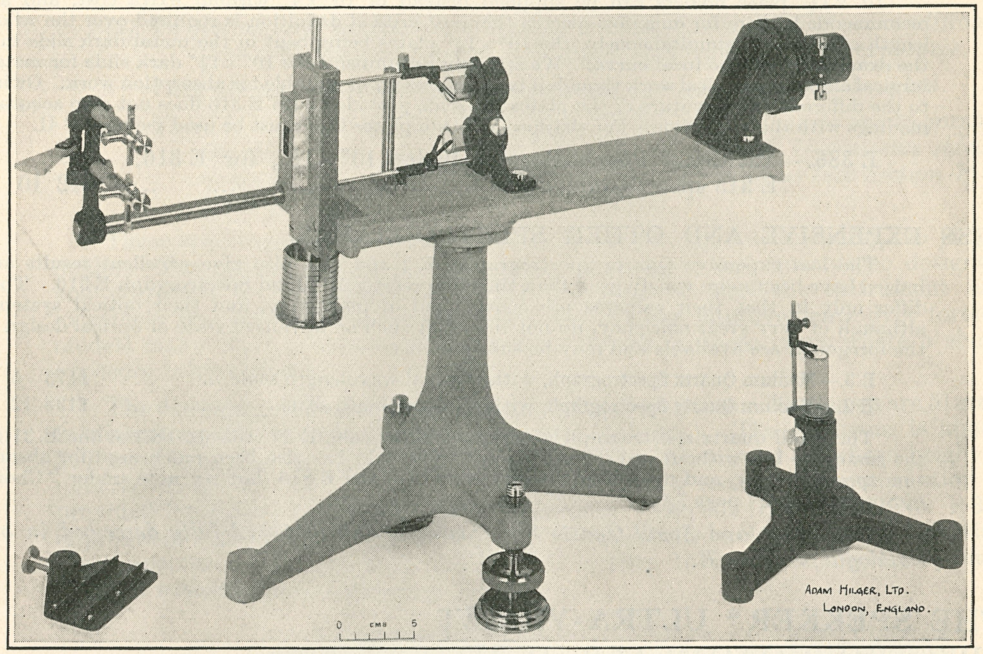

Fig. H 237—Spekker Ultra-Violet Photometer with H 265 Stand for filling tubes.

An important consideration in all such instruments is the method of illumination. Not only must a single light source be used to illuminate both light paths, but since this may vary in intensity from point to point, in a way that changes as the light source fluctuates, it is important that the illumination at the points of comparison shall come from the same part of the source and that the aspect in each case should be as nearly the same as possible. In the construction of this instrument both these conditions are strictly observed.

The alignment of ultra-violet spectrophotometers usually calls for great care, as the results may be vitiated by even slight errors, and there is frequently no evidence on the photographic plate that any such errors exist. Special attention has therefore been given to the matter in these instruments and a system evolved that obviates all difficulties. The light source forms a part of the instrument and its alignment can be checked in a moment. A special adapter is attached to the slit tube of the collimator and this receives and locates one end of the photometer, the greater part of the weight of the latter being taken by two levelling screws. This arrangement is preferable to the direct attachment of the photometer to the spectrograph (*a*) because the photometer can be instantly removed or replaced without disturbing any part of the spectrograph ; (*b*) because no undesirable strains such as might upset the adjustment of the spectrograph are introduced. Safety feet are also provided so that the instrument can stand independently of the spectrograph.

The instrument is more rapid than the intermittent exposure type or the forms employing polarising prisms, in which an initial loss of 50% of the available illumination must occur. It shares with the former the merit of simplicity of principle.

The Spekker photometer is provided with two means of supporting the necessary absorption cells. Ordinary forms of cell are carried on two platforms independently adjustable in height. Fittings are also provided for the new quickly detachable types of cell listed on page 15. These are so designed that a sixth of a turn of the cell attaches them to the instrument in accurate alignment, in which position they are then fixed by a simple clamping screw. This method of attachment is peculiarly valuable when the Hilger micrometer cells are being used, as its complete rigidity ensures easy and certain adjustment of the cell, using one hand only. The cells are parallel to one another and horizontal so that any length of cell can be used up to the limit (with the standard instruments) of 10 cms. Photometers for any desired greater length of cell can be quoted for. Although designed for use with the Hilger quartz spectrographs the Spekker photometer can be used with any spectrograph of sufficient aperture.

The adjustable aperture is controlled by a fine micrometer screw operated by a drum. The latter has a helical scale whose great length (about 40 inches) enables a very open division to be secured, a matter of special advantage in the higher densities. The scale is directly engraved in values of $\log \frac{I}{I'}$ * (known as the Density). Where I and I' are the intensities of the contiguous parts of the two halves of the spectrum line formed by radiation which has passed through the fixed and variable

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* For instance, the Judd Lewis sector photometer and the wire grid with which much experimental work has been done in the Hilger laboratories.

* There is, unfortunately, no universally accepted nomenclature for the various quantities used in the expression of absorption measurements. A list of most of the terms usually employed in absorption measurements will be found in Kayser's *Handbuch der Spektroskopie*, Vol. 3, p. 15. It should, however, be noted that the term " extinction coefficient " is usually applied not to the quantity so denoted by Kayser in the list cited above, but to that represented by a in the relation $\frac{I}{I'} = 10^{ad}$ where I is the light entering the medium, I' that transmitted and d the thickness of the medium traversed by the light. The term " extinction coefficient " was thus used by Bunsen and Roscoe (*Pogg. Ann. der Physik und Chemie*, Band C 1 (Band 177, of the entire series), p. 238) and has found such general acceptance that pending universal concordance of procedure we have decided to adopt it ourselves for the quantity in question.

" Let Jq be the intensity of the incident light which enters the medium, Jp the intensity remaining after its subsequent passage through a path length h, and $1/a$ the path length, passage through which reduces the light intensity to 1/10th : then

$$Jp = Jq . 10^{-ha}$$

where, a constant depending on the medium, is called by us the " extinction coefficient " (Trans. from reference cited). h is, of course, to be taken in centimetres."

In the text of this brochure we have substituted I for Jq, I' for Jp, and d for h.

Note that for the above simple relation to hold $Jq(I)$ and $Jp(I')$ are to be taken as signifying in the former case the light entering the liquid (not that incident on a cell containing it, part of which is reflected), and in the latter case the light after transmission through the liquid (not that emergent from a cell containing it).

In the present state of nomenclature in this field, workers are strongly advised to guard against error due to the use of terms such as " absorption constant," etc., by making sure what is meant by the term in each case.

Curves of absorption are usually best plotted with wavelength as abscissæ and extinction coefficients as ordinates.

apertures respectively (when no absorbing substances are interposed) under the circumstances described,

$$\frac{I}{I'} = \frac{\text{Area of fixed aperture}}{\text{Area of variable aperture}}$$

H 237.—Spekker Ultra-Violet Photometer, Research Model, complete with spark electrode holder, one pair of tungsten-steel electrodes and adapter for slit of Hilger Medium Quartz Spectrograph. (The adapter is easily fitted to any existing Hilger Medium Quartz Spectrograph.) Price £75 0s. 0d.

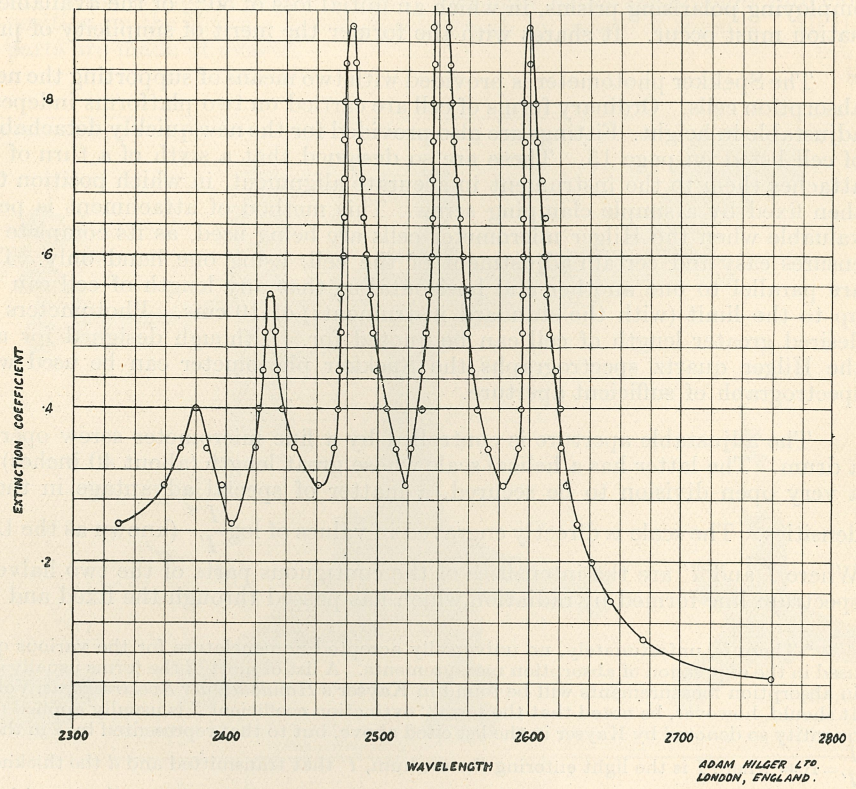
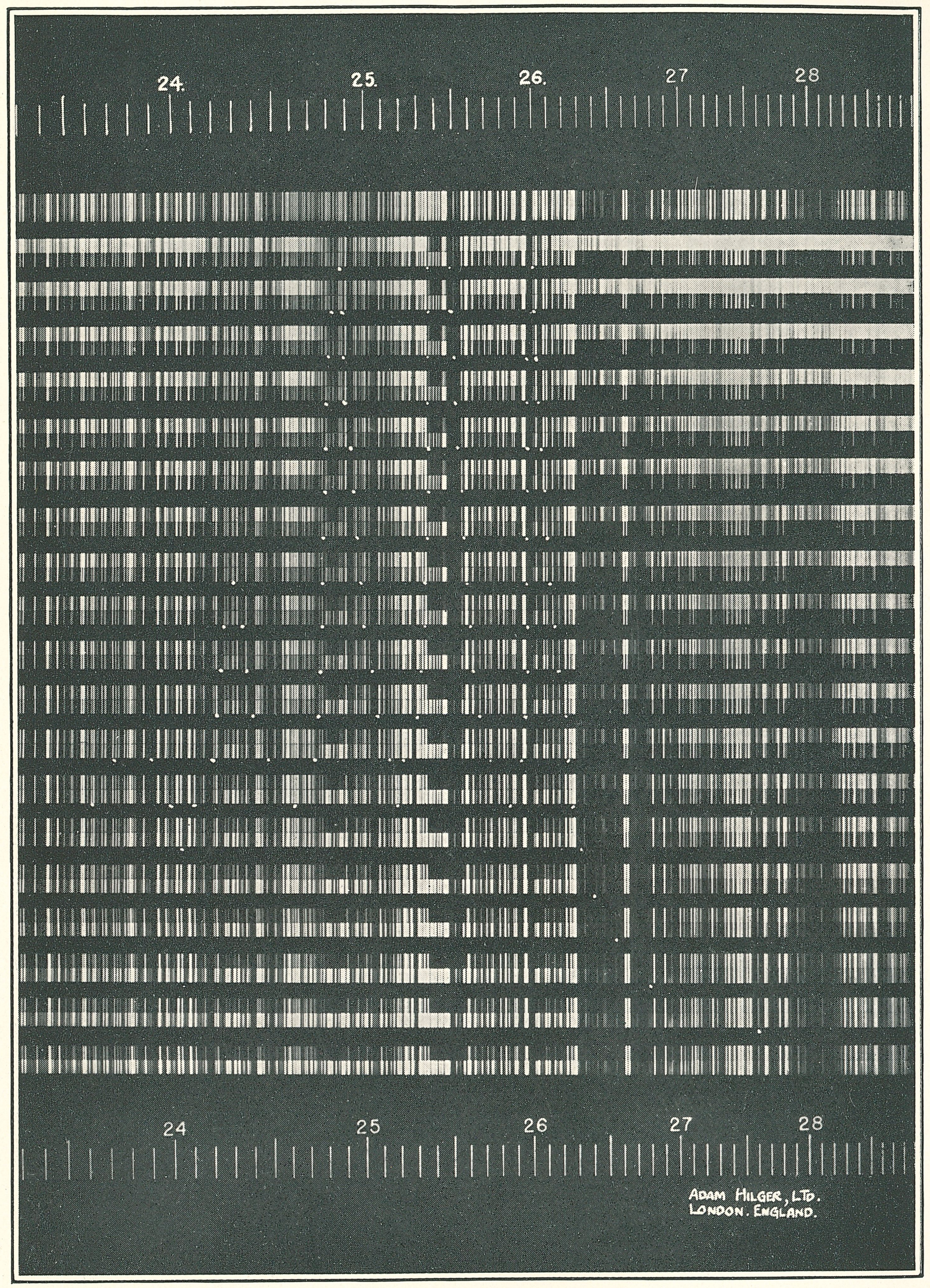


Fig. H 237a

Absorption Curve of Benzene (in Hexane). Strength of solution 1 in 3300. (See photograph, Plate 1, opposite).



ABSORPTION PHOTOGRAPH OF BENZENE (IN HEXANE) TAKEN WITH SPEKKER ULTRA-VIOLET PHOTOMETER (H. 237) AND MEDIUM ALL-METAL QUARTZ SPECTROGRAPH (E. 316).

Length of tube 2·0 cms. Minimum exposure 5 secs. See curve opposite. Enlargement × 2 of a portion of the photograph.

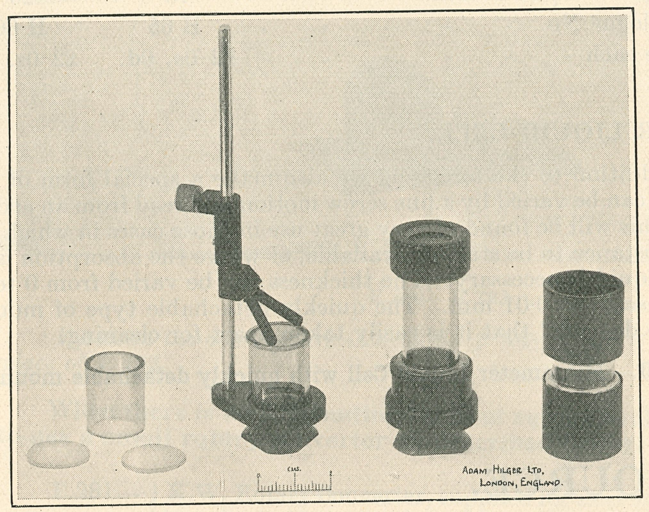
ACCESSORIES.

TUBES FOR LIQUIDS.

The lengths of tubes appropriate for various purposes differ considerably and the notes on page 7 are intended as a guide to those desiring to order tubes.

All the following tubes have an internal diameter of approximately, 14·5 *mm.*

Three forms of Absorption Tube for Liquids suitable for use with these photometers can be supplied, each form in several sizes.



Type A Type B Type C

Fig. H 261, H 256, H 65, Tubes for liquids.

TYPE A.

Capless Tubes.—These consist of a separating ring and two quartz end plates which are held together by a simple quickly detachable mount which carries a rod on which slides a clip. They possess the advantages of simplicity of construction and complete absence of cement. The ends of the tubes are carefully ground and polished.

H 261.—One pair of quickly detachable mounts for capless tubes. £4 0 0

H 264.—Quartz End Plates, per pair 0 15 0

Separating rings.

Length of liquid in mms.	1	2	2·5	4	5	10	20	40
Catalogue No.	**H 248**	**H 249**	**H 250**	**H 251**	**H 252**	**H 253**	**H 254**	**H 255**
Price each	17s. 0d.							

H 265.—Stand for Filling Tubes. This is a simple stand which holds the tubes firmly while they are being filled, and will be found a very great help in this operation ... £2 0 0

TYPE B.

Tubes with screw-on end caps fitted with quickly detachable mounts. These tubes correspond with the more usual form of absorption tube for Sector Photometers and are supplied in the following sizes :

Length of liquid in mm.	5	10	20	40
Catalogue No.	**H 256**	**H 257**	**H 258**	**H 259**
Price each	£2 15s. 0d.	£2 5s. 0d.	£2 5s. 0d.	£2 5s. 0d.

TYPE C.

Tubes with plain screw-on end caps, to lie in trough, can be supplied in the following sizes :

Length of liquid in mm.	10	20	40
Catalogue No.	**H 65**	**H 66**	**H 67**
Price each	£2 0s. 0d.	£2 0s. 0d.	£2 0s. 0d.

MICROMETER LIQUID CELL.

In addition to the foregoing we also make a special form of cell in which the thickness can be varied by a fine screw motion and read from an accurately engraved drum. This will be found of very great use in those cases in which there is but little of the substance to be studied available, or where the absorption is such that a thin layer of liquid is necessary. The thickness can be varied from 0 to 5 mm. and read from the scale to 0·01 mm. The quickly detachable type of mount is used. The tube is so designed that it is easily taken apart for cleaning.

H 260.—Micrometer Liquid Cell with quickly detachable mount. £17 0 0

LIGHT SOURCE.

The Spekker Ultra-violet Photometer carries its own light source, in the form of a spark electrode holder. Accessories for producing the spark will be found described below. When it is desired to use a light source having a continuous ultra-violet spectrum recourse can be had to the special Hydrogen Vacuum Tubes described on pages 17-18.

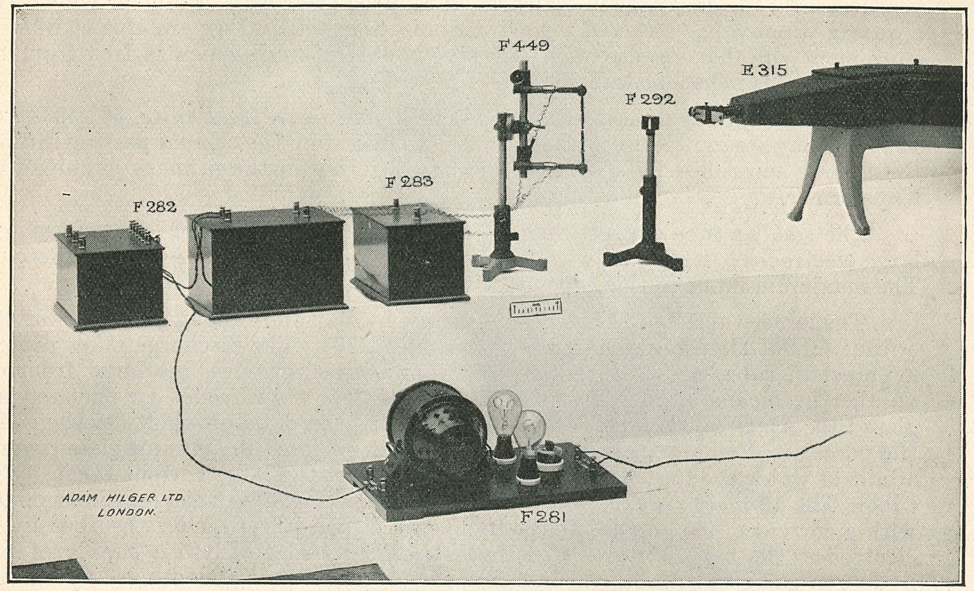
OUTFIT FOR SPARK.

The outfit described below has been carefully selected as the simplest and most satisfactory means of producing a spark suitable for Ultra-Violet Spectrophotometer.

F 282.—¼ K.W. Transformer and Auto-transformer, which can be used on any A.C. supply from 75 to 220 volts. The secondary gives 8,000, 10,000, 12,500, or 15,000 volts, any of which may be selected by using the appropriate auto-transformer tappings in accordance with the Instructions for Use £20 0 0

F 283.—Condenser of 0·005 m.f. capacity designed as a part of the set £9 0 0

The above pieces of apparatus are enclosed in polished mahogany cases with ebonite tops and nickel-plated terminals.



F 281—F 283

F 449 in the above figure is actually F 580, while F 15 is now recommended in place of F 292.

When there is no Alternating Current supply available it will be necessary to use a small rotary converter as described below.

F 281.—¼ K.W. Rotary Converter, supplied for D.C. input at either 110 volts or 220 volts, delivering 60 cycles A.C. at 75 volts or 150 volts respectively. It is mounted on a teak baseboard with switch and lamp resistance for starting. Stout terminals for input and output are fitted ... £26 0 0

F 406.—Tungsten Steel Electrodes.—Small, conveniently shaped, pieces of steel rod containing Tungsten and other metals, carefully selected to give a spark spectrum rich in ultra-violet radiations. By trial these electrodes have been proved to be superior to the Jones electrodes formerly used both in richness of emission and slowness of disintegration. They can be used for absorption measurements daily for many weeks without renewal, and for a whole day without readjustment. These electrodes suffice as a light source for all routine examinations.
Per pair £0 5 0

CONTINUOUS ULTRA-VIOLET LIGHT SOURCE.

A source of continuous radiation in the ultra-violet is for some research work a desirable accessory for absorption measurements in this region. Several workers have successfully used the spark under water for this purpose obtaining good results combined with a short time of exposure. Such a source has, however, a number of inconvenient features among which may be mentioned cost of the equipment, noise of the auxiliary spark as well as of that under water, the necessity for distilled water in quantity, etc.

Recently the discharge in hydrogen at reduced pressure in a tube provided with a quartz window has received a good deal of attention, and we are able to offer an equipment suitable for use with our spectrophotometers which is free from the inconveniences mentioned above.

The tubes are as described by Bay and Steiner (*Zeit. für Physik*, **59**, pp. 48-52, 1929). They are excited by a transformer. In operation the current passing through the tube is controlled by a suitable sliding resistance in the primary circuit of the transformer.

The smaller tube F 656, which is supplied ready filled, is of " H " form with large electrodes. It is filled with hydrogen at a pressure of 3 to 4 mm. of mercury. The maximum input to this tube is 250 m.a. at 1500 to 2000 volts.

The larger tube F 657* has been designed by Bay and Steiner to give an intense output (about 2·5 times as intense as that of F 656). The discharge takes place in a porcelain tube on which cylindrical aluminium electrodes, insulated from one another by means of mica discs, are mounted. These electrodes are enclosed in a glass tube which is provided with a quartz window in close proximity to the end of the porcelain discharge tube. This tube is again enclosed in an outer glass cover to admit of water cooling which is essential in view of the large current taken by the tube. The discharge is excited by a transformer giving 4000 volts on the secondary with a current of 0·5 amps. As the hydrogen gas is rather rapidly absorbed by the electrodes, the tube is not sealed, but should be connected to a supply of pure hydrogen gas and suitable vacuum pumps. If gas is passed continuously through the tube the current may be somewhat increased for short intervals.

The catalogue numbers for the equipment are as follows :

	PRICE IN GT. BRITAIN.	PRICE ABROAD.
F 656.—Type I Hydrogen Vacuum Tube (filled) ...	*Prices under revision* *Will be furnished on application*	
F 657.—Type II Hydrogen Vacuum Tube (unfilled)		
F 658.—2 K.V.A. Transformer for exciting the above tubes. Input 110 v. (or 220 v.) single phase alternating current. Output 4000 volts with a current of 0·5 amps. Frequency 50 Herz.		
F 659.—Regulating Sliding Resistance 9 amp. 11 ohm.		

Please state voltage of electric circuit, when ordering.

APPARATUS FOR EXAMINING AND MEASURING SPECTROGRAMS.

A special advantage of the equipment described in this booklet is the simplicity of the apparatus necessary for examining the spectra. The dispersion is sufficient to do away with any necessity for a viewing microscope such as is necessary with spectrographs taking smaller plates.

NEGATIVE VIEWING STAND

The Negative Viewing Stand is a convenient means of supporting spectrum negatives during examination. It is simply and strongly constructed and can be folded flat when not in use. In Figure F 644 it is shown erected ready for use.

The main sloping board has a rectangular aperture with slightly recessed edges, taking a standard 10 × 4 in. plate. Smaller sizes can be carried in loose frames or adapters. The sloping position of the plate is most convenient for viewing and

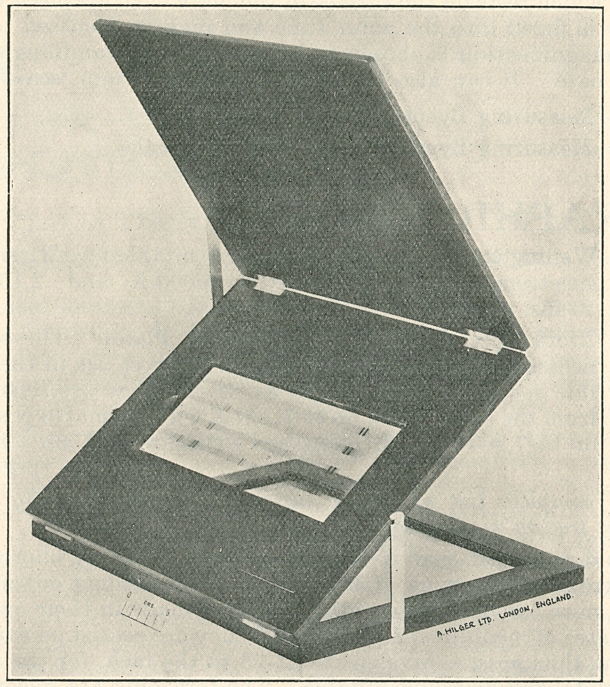


Fig. F 644

marking negatives. A plate of white glass in the flat base provides diffused light from any convenient source, or window, while the upper flap shields the operator's eyes from any light other than that passing through the negative. When folded up this latter flap protects the glass plate and any negative that may be left in place.

The apparatus is made of well seasoned black polished wood.

F 644.—Negative Viewing Stand £1 18 6

EYEPIECE FOR SPECTRUM MEASUREMENT.

This eyepiece is a useful accessory for spectrophotometric work.

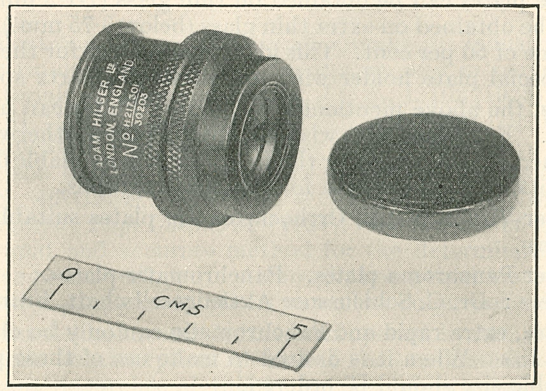


Fig. H 245

The instrument consists of an outer tube, with substantial knurled rings, the lower end of which rests on the surface of the plate. An eyepiece with an extra large field of view is fitted into the outer tube and may be focussed by sliding it in the latter. Its magnification is chosen to be suitable for examining spectrograms with the greatest ease. It can also be supplied with 1/10 mm. scale

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*Another form is about to be put on the market (Oct. 1931) and will be fully described in a later announcement.

H 245.—Measuring Eyepiece (without scale)	£1 19 0
H 217.—Measuring Eyepiece (with 1/10 mm. scale).	2 10 0

PHOTOGRAPHIC PLATES.

	F 144.—Wellington Anti-Screen Plates are suitable for all general spectrographic work between 5,000 A and 2,150 A. 10 ins. × 4 ins. ... ... per doz.	£0 9 6
(OPT)	**F 140.—Ilford Special Rapid Panchromatic Plates.** These are necessary where the main part of interest lies in the visible spectrum towards the red end. They are sensitive from the ultra-violet up to 7,200 A with normal exposures or to 7,900 A with prolonged exposure. 10 ins. × 4 ins. per doz.	0 13 9

(*For a complete list of plates suitable for Spectrography see special leaflet* S.B.42/2 *post free on application*).

It should be noted that it is not essential to obtain photographic plates for Hilger Spectrographs from us. Customers who are resident outside the British Isles may find it more convenient to purchase plates made in their own countries. Any fine grain plates of medium speed, provided they are coated on sufficiently thin glass (1 to 1·2 mm. thickness, equivalent to 22-23 to the inch, for the standard 10 ins. × 4 ins. dark slide) will be found suitable. The foregoing are selected by actual trial in our laboratories.

In America, suitable plates made by Eastman Kodak, and obtainable in sizes suitable for our spectrographs from any of their agents are the following :

Eastman 40. Sensitive from the ultra-violet up to 5000 A. Of high sensitivity, medium grain and contrast.

Eastman 33. Sensitive from the ultra-violet up to 5000 A. Of medium sensitivity, small grain, and high contrast.

Wratten Panchromatic. Sensitive from the ultra-violet evenly up to 7200 A with slight dip at 5250 A. Of high sensitivity, medium grain, high contrast.

Wratten M. Sensitive from the ultra-violet quite evenly up to 7000 A. Of medium sensitivity, fine grain, and very high contrast.

The above plates can be obtained on thin glass (1-1·2 mm.) on special request. They can also be obtained on extra thin glass (below 0·75 mm.) on special order at an increase of price of 50 per cent. This glass is necessary for the plates 1¼ inches wide used in the special plate holder with the all-metal quartz spectrographs.

In Europe, the above mentioned Wellington Plates can usually be supplied by us from stock. For those who wish to obtain plates otherwise than from us the above mentioned Kodak plates, or the following, are available direct from the makers and their agents, in sizes suitable for our spectrographs.

Schleussner Viridin plates, Orthochromatic plates suitable for general spectrography.

Schleussner Panchroma plates. Panchromatic plates.
Makers : Dr. C. Schleussner Aktiengesellschaft, Frankfurt am Main.

Agfa Plates, extra rapid and Panchromatic can only be obtained in the 9 by 24 cms. size. When it is desired to make use of these plates dark slides of a suitable size should be ordered.

In many European countries Messrs. Ilford Ltd. have sole agents, to whom orders for their manufactures should be addressed.

PART II.

OUTFITS FOR VISUAL SPECTROPHOTOMETRY.

RECENT APPLICATIONS OF VISUAL SPECTROPHOTOMETRY TO CHEMICAL INVESTIGATIONS.*

Industrial laboratories are now rapidly adopting the visual spectrophotometer as a reference instrument in many of their problems. The following investigations, all of recent date, show the range of application of this type of instrument. An accurate and rapid method of hydrogen ion concentration determination can readily be applied to plant control work. (Brode, *J.A.C.S.*, 46, 1924). In the dye industry the determination of concentration and purity, since the absorption spectrum of a dye gives a measure both of its colour purity and concentration can readily be made. Standard curves of pure commercially important dyes have been prepared by the Dye Laboratory of the U.S. Bureau of Standards on a number of the most important dyes, Gibson et al., *Sci. Papers Bur. Stds.*, 18 (1922), Appel and Brode, *Ind. and Eng. Chem.*, 16, 1924 ; Appel, Brode and Welch, *Ind. and Eng. Chem.*, 18 (1926), Brode, *Ind. and Eng. Chem.*, 18, 1926. In these papers data are given on the standard absorption curves for a number of dyes, methods for the spectrophotometric determination of the amount of dye present, detection of impurities, and in certain cases the quantitative estimation of the impurity present. In the quantitative estimation of dyes of known composition to determine the amount of salt or other non-absorbing material present, it is not necessary to determine the entire absorption band, but only the intensity of absorption of the maximum of the band. The ratio of this to the maximum absorption intensity of the standard curve gives the amount of dye present.

Other commercial applications include the absorption spectra of concentrated sugar solutions for determining the colour of sugar (Peters and Phelps, *Bureau of Stds. Tech. Papers* No. 338 (1927), the study of coloured glasses used in photographic filters, for eye protection and the like (Gibson, *J. Opt. Soc. America*, 13, 267 (1926), *Sci. Papers. Bur. Stds.* 18 (1922).

Reflection spectra measurements have been applied to the study of paint samples (Gardner, *Physical and Chemical Examination of Paints, etc.* (1925), chap. III. p. 34), paper samples, dyed fabrics and the like to measure colour intensity, to compare samples and obtain quantitative data on the rate and nature of fading of exposed samples.

Other applications not so directly of interest to industry, are the following spectrophotometric determinations of adsorption, and in particular adsorption by biochemical materials. (Fodor and Riwlin. *J.C.S.*, I. 102 (1926) ; Fodor and Mayer, *Kolloid Z.*, 40, 41 (1926) ; and Riwlin, *J.C.S.*, II, 2300 (1926). The dissociation constants of indicators can be accurately determined by a spectrophotometric examination of the indicator in solutions of known hydrogen ion concentration. (Brode, *J.A.C.S.*, 46 (1924) ; Thiel and Wülfken *Z. anorg. Chem.* 136, 393 (1924) ; Mellon and Martin, *J. Phy. Chem.*, 31 (1927). By the use of the same principle of observation a rapid and accurate method for the determination of hydrogen ion concentration has been developed. Although the method is colorimetric in principle it may be applied to coloured solutions as well as colourless solutions.

An important field of research has been opened by the study of the effects of physical conditions on absorption spectra of various materials ; the following are examples of recent researches of this type. The absorption spectra of rare earth crystals in a magnetic field and at low temperatures, Becquerel, Onnes and Hass, *Compt. rend.*, **181**, 758, 1925. The influence of heat on the absorption spectra of coloured alkali halides, Phipps and Brode, *J. Phys. Chem.*, **30**, 507 (1926); Flechsig, *Z. Physik*, **36**, 605 (1926); Studies of Beer's and Kundt's laws, Rossi and Basini, *Annali. Chim., Appl.* **16**, 299, 1926; Vaillant, *Compt. rend.*, **184**, 1659 (1927); Szilárd *Bio. Chem. Z.*, **170**, 185 (1926).

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* This has been extracted from a bibliography prepared by Dr. W. R. Brode. Copies of which can be supplied *post free* on request.

Independent investigators searching for element No. 61 (Illinium), used visual absorption spectra measurements in determining the cutting points in separating fractions of rare earth salts. Harris, Yntema and Hopkins, *J.A.C.S.*, **48**, 1585, 1594 and 1598 (1926); Rolla and Fernandes, *Z. anorg. Chem.*, **157**, 371 (1926). The absorption spectra of various elements and salts in the vapour state has been the subject of a number of recent investigations, Sowerby and Barratt, *Proc. Roy. Soc. A.* **110**, 190 (1926), Zumstein, *Phys. Rev.*, **26**, 765 (1925); Van Heel, *Proc. K. Akad Wetensch*, Amsterdam, **30**, 95, 1927.

A method has been proposed for the spectrophotometric identification and determination of nitrates and nitrites by their colour reactions. Tassilly and Savoire, *Compt. rend.*, **183**, 887 (1926). Similar applications have been made to the analysis of cobalt complexes of organic amines. Uspenski and Techibisov, *Trans. Inst. Pure Chem. Reagents*, Moscow, p. 32 (1927); constitution of ferro and cupri nitric oxide salts and ferro nitro sulphide compounds, *Ber.* **59 B**, 406, 411 (1926).

CHOICE OF DESIGN.

For these chemical applications it is of prime necessity that the spectrophotometer should give exceedingly accurate measurements (*a*) of the high extinction coefficients corresponding with the peaks of absorption, (*b*) of wavelengths.

The Hilger-Nutting Spectrophotometer was designed with these points in mind. In economy of light it is inferior only to the Hüfner type, (see page H 23 of our General Catalogue). The Hüfner instrument, however, is not very convenient as it does not permit of the use of separated tubes for solutions, is not quite so accurate in wavelength measurements, and is not so secure against damage, or loss of adjustment, as is the Hilger-Nutting Spectrophotometer.

Where the spectrophotometer is required in connection with colour measurements the conditions are different; here accuracy of measurement in the most freely transmitted spectral regions is more important.

Adam Hilger, Ltd., will be glad to advise in the selection of instruments where it is desired by taking spectrophotometric curves to determine the colour characteristics of colouring materials. The routine control of the colours of such materials, however, is best effected by the Colorimeter, see pages H 35-38 of our General Catalogue.

RECOMMENDED OUTFITS FOR VISUAL SPECTROPHOTOMETRY.

COMPRISING EVERYTHING NEEDED FOR QUANTITATIVE SPECTROPHOTOMETRY IN THE VISIBLE.

*H 105.	**Hilger-Nutting Industrial and Research Spectrophotometer** with 100 c.p. Pointolite Lamp, Resistance for **DIRECT CURRENT** with one pair of tubes (H 225) ...	£178 0 0
or		
*H 106.	**Hilger-Nutting Industrial and Research Spectrophotometer** with 150 c.p. Pointolite Lamp and Resistance for **ALTERNATING CURRENT**	£178 0 0

A pair of tubes H 225 is included with the instrument, for additional tubes see page 26. For alternative apparatus see p. 27.

*Please state voltage of supply in ordering.

DESCRIPTION OF RECOMMENDED VISUAL SPECTROPHOTOMETER.

The form of Hüfner Spectrophotometer made by us since 1904 was designed for research on photographic plates, and for this purpose it has given general satisfaction. While it has also been very serviceable in general chemical work it presents for such purposes several disadvantages. When, therefore, we turned our attention to the development of a Spectrophotometer which should be as convenient and accurate as possible for general chemical work, we adopted as the basis of such an instrument—after a careful survey of the main types of photometer available—the form of polarisation photometer described by P. G. Nutting (*see* reprint No. 155, *Bulletin of the Bureau of Standards*), using it in conjunction with our Constant Deviation Wavelength Spectrometer.

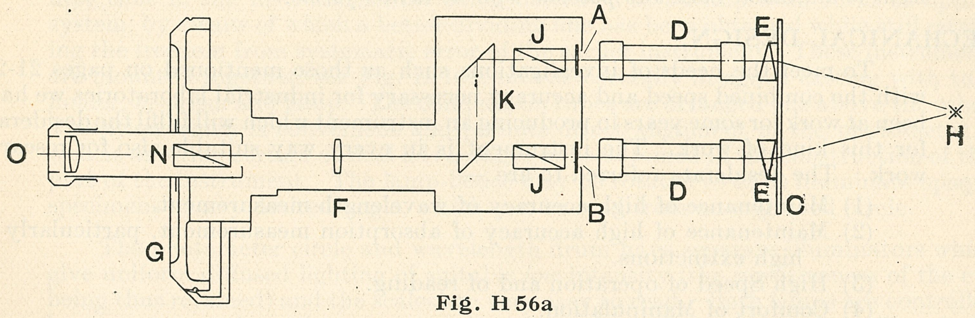

Fig. H 56a

Considerable alterations were made in the design of the photometer to fit it for the purpose in view, but certain essentials remain; while every modification has been the subject of careful consideration.

The features of chief interest to the user are as follows:

(1) One light source is used for both beams of light.

(2) There is ample separation between the two beams (the distance between the centres of the beams being 38 mm.).

(3) The circle is divided both in " densities " and degrees.

The Optical System of the more recent models of this instrument is shown in the accompanying diagram, Fig. H 56a, while the general appearance of the complete apparatus is shown in Fig. H 105. Light from a suitable source H falls upon a device C, consisting of two achromatic deviating lens-prisms E, on a stand, from which it emerges as two parallel pencils. These pass through absorption tubes D into the photometer through windows A and B. Two square-ended polarising prisms whose planes of polarisation are mutually perpendicular, receive the two pencils, which are later combined to form two closely juxtaposed fields by a prism K. The object glass O focusses an image of the dividing line on the slit of the accompanying spectroscope. A third polarising prism N mounted in the circle G produces, when rotated, a variation in the relative intensities of the two beams such that,

$$\frac{I_0}{I} = \tan^2\theta$$

where I_0 = intensity of light incident upon A.

I = intensity of light incident upon B.

θ = the angle through which the prism N must be rotated in order that equality of intensity may be obtained in the two fields.

The divided circle is engraved with a scale of densities $\left(\log.\ \frac{I_0}{I}\right)$ as well as degrees, and a reading lens is so placed that readings may be made without quitting the spectroscope eyepiece.

An important feature of this system is the provision of two polarising prisms whose planes of polarisation are mutually perpendicular. The majority of light sources are partially polarised to a more or less appreciable extent and the provision of the two prisms nullifies any possible error likely to arise from this cause. More perfect juxtaposition of the double field is obtained with the present system than on our earlier instruments (which were more nearly like that described by P. G. Nutting in his original paper), while it is free from systematic errors which might be introduced by small residual strains in the prism or by the small amount of double refraction produced by a film of cementing substance.

Our laboratory finds that with this instrument a greater accuracy of reliable measurement is attainable than was possible with its earlier forms.

MECHANICAL DESIGN.

To meet the needs of investigations such as those mentioned on pages 21-22, with the combined speed and accuracy necessary for industrial laboratories we have been at work for some years in producing an instrument which will fulfil the desiderata for this kind of work. The instrument is in every way suitable also for research work. The desiderata referred to are :—

(1) Maintenance of high accuracy of wavelength measurement.
(2) Maintenance of high accuracy of absorption measurement, particularly in high extinctions.
(3) High Speed of operation and of reading.
(4) Comfort of Manipulation.
(5) Mechanical suitability for somewhat rougher usage than is expected in an Academic laboratory.
(6) Permanency of set up and adjustment.
(7) Adequate instructions for use.

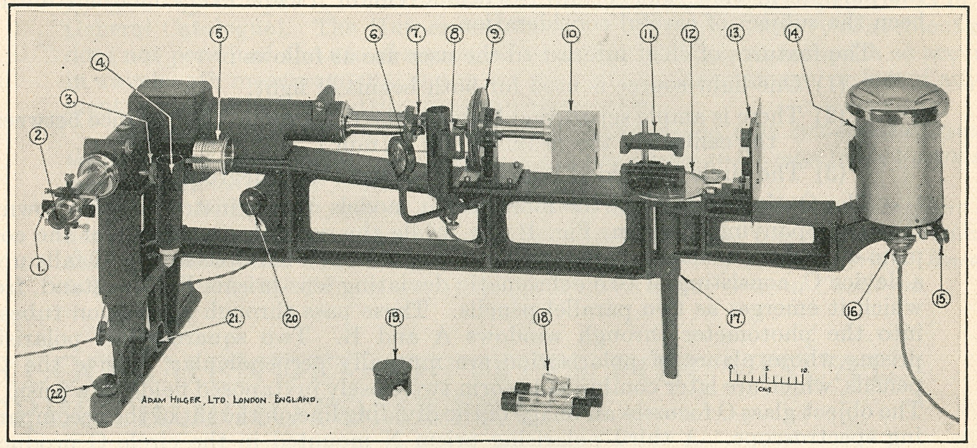

Fig. H 105

Hilger-Nutting Research and Industrial Spectrophotometer.

1 Shutters limiting the field of view.
2. Eyepiece.
3. Focussing adjustment of spectrometer.
4. Illuminating lamp for Wavelength Drum.
5. Wavelength Drum.
6. Reader lens for Photometer circle.
7. Spectrometer slit.
8. Illuminating lamp for Photometer circle.
9. Photometer circle.
10. Photometer Box.
11. Absorption tubes support.
12. Divided circle for light source.
13. Double Beam device.
14. Lamphouse.
15. Lamp adjustments.
16. Pointolite Lampholder.
17. Centre of rotation of light source.
18. Tubes for liquids.
19. Protective cover for slit.
20. " Dimmer " for reading lamps.
21. Handle for rotating photometer circle.
22. Switch for reading lamps.

The instrument embodies many improvements suggested by Dr. Wallace R. Brode, Ph.D., and found by trial with an actual instrument to render it capable of work of the very highest precision. (W. R. Brode : " The Analysis of the Absorption Spectrum of Cobalt Chloride in Concentrated Hydrochloric Acid." *Proc. Roy. Soc. A.* **118**, page 286).

The Hilger Nutting Industrial Spectrophotometer consists essentially of a Hilger Nutting Photometer H 56 and Hilger Wavelength Spectrometer of the latest type D 77. An important improvement which has been made and employed for the first time in the instrument now being described is an improved form of optical system, by means of which a better dividing line has been obtained while still retaining the freedom from systematic error of the earlier instrument. These instruments are mounted together, see Fig. H 105, on one carefully designed casting with tube holder, bi-prism and lamp. The comparison tubes are arranged one above the other, a position which is convenient and permits direct alignment of the photometer as well as allowing certain optical advantages to be obtained in the construction of this part of the instrument. The lamp-house may be rotated so as to illuminate opaque specimens at any desired angle, which can be read from an engraved circle.

The photometer circle and wavelength drum have separate illuminators which give uniform diffused lighting of suitable *low* intensity (the sensitiveness of the eye being thus retained) and the scales are very easy to read. Both lamps are controlled by a push switch, and current is taken direct from the main supply. The photometer circle has a slow motion operated by a drum conveniently near the observer, and close to the wavelength drum and focussing motion. The lighting switch is also near the slow motion, and *thus all controls are grouped near together, and so placed that they can be operated for long periods without fatigue.* The light source consists of a 100 c.p. pointolite lamp and resistance for direct current, or a 150 c.p. lamp for alternating current. Means are provided for varying the brightness of the scale lamps to suit the observer.

Every instrument is carefully adjusted at our works and *is ready for use on inserting the light source and centring it ; this being effected by two adjustments in the lamphouse only,* so that the instrument can be got into working order in a few minutes, and will remain in perfect adjustment.

Complete instructions are, however, sent out with every instrument so that the adjustment can be checked if desired.

H 105.—Hilger-Nutting Industrial and Research Spectrophotometer with 100 c.p. Pointolite Lamp, Resistance for Direct Current, with one pair of tubes (H 225) £178 0 0

H 106.—Hilger-Nutting Industrial and Research Spectrophotometer with 150 c.p. Pointolite Lamp and Resistance for Alternating Current, with one pair of tubes (H 225) £178 0 0

(Please state voltage required in ordering.)

USEFUL ACCESSORIES.
FOR COMPARISON OF LIGHT SOURCES.

For methods of measuring the Relative Spectral Distribution of Light Sources see the booklet, " The Determination of the Relative Spectral Distribution of Light Sources by the Hilger-Nutting Spectrophotometer." 1s. 8d. post free.

F 258.—Pair of Neutralising Lenses in Mounts. These are negative lenses which, when fitted to the parallelising device, enable the apparatus to be used for comparing sources ... ... per pair £2 2 0

FABRIC HOLDER.

A special attachment for the measurement of the absorption spectra of opaque substances can be fitted. It is readily attached to the divided circle adjacent to the light source, and consists of a vertical mount, for the fabric and a comparison surface, rotatable about a vertical axis. It is provided with an index enabling the angle at which the surfaces are presented to the incident light to be read from the circle. It includes a 500 c.p. Pointolite lamp in a housing replacing the 100 c.p. lamp. It has been found in practice that the 100 c.p. lamp is insufficiently brilliant for measurements on reflection from surfaces. In use the light source is set at right angles to the optical axis of the instrument. For suitable resistances see F 243 and F 244 opposite.

H 168.—**Fabric Holder,** for Hilger-Nutting Industrial and Research Spectrophotometer	£36	0	0

ACCESSORY FOR THE MEASUREMENT OF THE ABSORPTION SPECTRA OF REFLECTING SURFACES.

This accessory is so designed that a beam of light can be reflected back and forth two or more times, between two specimens of the same reflector before entering the photometer box, thus increasing the absorption to a measurable value.

H 175.—**Accessory for measuring the Absorption of Reflecting Surfaces** ...	£12	10	0

ABSORPTION TUBES.

The lengths of tubes appropriate for various purposes differ considerably and the following notes are intended as a guide to those desiring to order tubes.

In investigations carried out at the Bureau of Standards, Washington, described in *Scientific Paper* No. 440, June 1922, " The spectral transmissive properties of dyes " (seven dyes permitted in foodstuffs) the investigators used cells of 2 cms. length ; as did also Walter C. Holmes. *See Industrial and Engineering Chemistry,* August 1923 " Acid Dyes of the Patent Blue Type " and January 1925 (basic fuchsins). This 2 cm. Tube Catalogue No. H 225 is a very suitable length for general absorption work.

The following tubes should always be ordered and used in pairs :

H 223.—**Tube for Solutions.**	5 mm. length of liquid ...	£2	5	0	each.
H 224.—**Tube for Solutions.**	10 mm. length of liquid ...	1	15	0	,,
H 225.—**Tube for Solutions.**	20 mm. length of liquid ...	1	15	0	,,
H 226.—**Tube for Solutions.**	40 mm. length of liquid ...	1	15	0	,,
H 58.—**Tube for Solutions.**	100 mm. length of liquid ...	1	19	6	,,

The above tubes are accurate in length to ±0·01 cm., and have screwed end caps. Their approximate internal diameter is 14·5 mm. H 58 is fitted with a central filling cup.

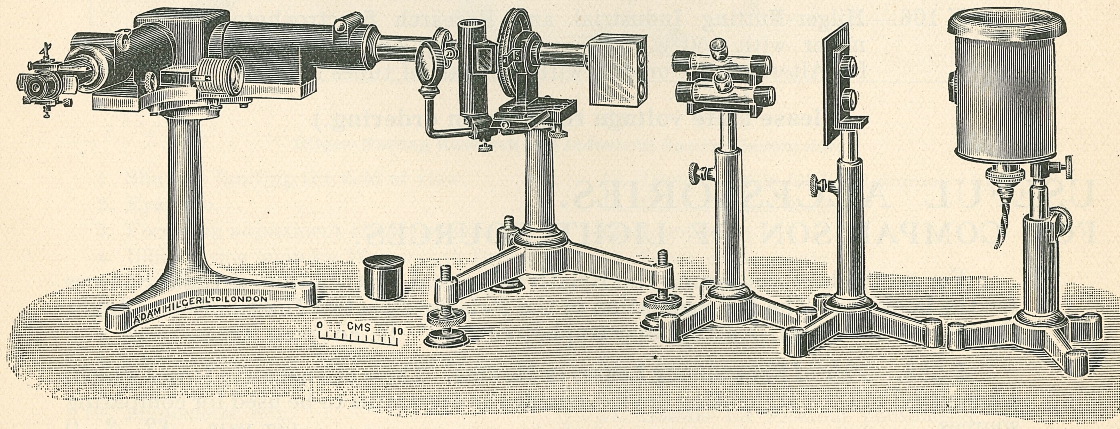

Fig. D 77, H 56

DESCRIPTION OF ALTERNATIVE OUTFIT.

Where a good Spectrometer is available, or where Spectrophotometry has to be carried out occasionally only, it is recommended that the Photometer should be separate from the Spectrometer. A complete outfit of this kind consists of a Hilger Wavelength Spectrometer with light prism (D 77 or D 1/4) with Nutting Photometer and equipment as described below.

The recommended outfit is shown above (Fig. D 77, H 56). Except for such details as are obviously peculiar to the Research and Industrial Model (*i.e.* centralised controls) the separate instruments are precisely as those embodied in that instrument.

SPECTROPHOTOMETRY.

*H 56.—**Hilger-Nutting Photometer** shown in figure D 77, H 56, with levelling screws, and including beam parallelising device and small electric lamp for illumination of the divided circle	£77	0	0
†D 77.—**Wavelength Spectrometer 1926 Model,** complete with shutter eye-piece, and prism of 1·65 refractive index for D (see Section D)	67	0	0
H 57.—**Raising and Lowering Stand for Holding Tubes of Absorbing Liquids,** taking tubes 10 cm. long and upwards	5	7	6
‡H 225.—**2 Tubes for Solutions,** length of liquid 20 mm.	3	10	0

LIGHT SOURCE.

*F 215.—**Pointolite Lamp 100 c.p.** (for direct current)	1	10	0
*F 216.—**Resistance for Pointolite Lamp** above	3	10	0
F 340.—**Lamphouse suitable for 100 c.p. Direct Current " Pointolite " Lamp.** Constructed with iron body and well ventilated. Rack and pinion, raising and lowering stand, suitable for all cases where accurate adjustment of the light source is required. (*Not including lamp or resistance*)	7	10	0
(*Please state voltage of supply in ordering.*)			
Total for D. C. Outfit	£165	7	6
or *F 240.—**Pointolite Lamp for Alternating Current 150 c.p.** consuming 2 amperes ionising current 7 amperes	£1	10	0
*F 241.—**Resistance Box for Alternating Current Lamp**	5	10	0
F 344.—**Light-tight Box** for F 240 A.C. lamp or for 500 c.p. Pointolite Lamp	13	10	0
(*Please state voltage of supply in ordering.*)			
Total for A.C. Outfit	£173	7	6

ACCESSORIES.

For measuring very high densities, *i.e.* high absorptions, or for making measurements in the extreme red or violet ; also for measuring reflective power of fabrics, papers, etc., a 500 c.p. Pointolite lamp is recommended.

*F 242.—**500 c.p. Pointolite Lamp**	£2	10	0
*F 243.—**Low Voltage (100-120 v.) Resistance for above Lamp** for Direct Current	9	10	0
*F 244.—**High Voltage (200-250 v.) Resistance for above Lamp** for Direct Current	12	10	0
*H 230.—**Fabric Holder** for Nutting Photometer, suitable for use in spectrophotometric measurements of the reflections from papers and fabrics. A rotatable mount on which the comparison " white " and the coloured material under test are held, are rotated so that they maintain the same angle of reflection, which is read from a scale and vernier to 1°. These are mounted in an enclosed lantern with a 500 c.p. Pointolite lamp F 242, reflectors and condensers concentrating the light on the fabric. On tripod with levelling screws. (*For suitable resistances for the Pointolite lamp, see* F 243 *and* F 244 *above.*) For Direct Current only	45	0	0

* Important.—The supply voltage (and, for Alternating Current, the frequency) for which they are required should be stated at the time of ordering these items.

†Where cost is a consideration the following may be substituted for D 77.

D 1/4.—**Wavelength Spectrometer with Prism of 1·65 Refractive Index for D,** accurately calibrated in wavelengths, with protective cover to prism table	£53	0	0
F 40.—**Shutter Eyepiece** for Wavelength Spectrometer, with lateral adjustment to bright pointer	7	7	0

‡For other suitable Absorption tubes see opposite page.

PART III.

PHOTO-ELECTRIC OUTFIT FOR ABSORPTION MEASUREMENTS IN THE ULTRA-VIOLET.

The following items are required for carrying out these measurements :

MONOCHROMATIC ILLUMINATING SYSTEM.

D 33.—**Ultra-violet Monochromatic Illuminator and Quartz Wave-length Spectrometer**	£144 18 0
—**Preliminary Dispersing Instrument**	*Price on application*

PHOTOMETER.

H 267.—**Photo-electric Photometer** as described below, including motor for driving sector disc, cells, and batteries ...	*Price on application*

LIGHT SOURCE.

F 656.—**Hydrogen Vacuum Tube** (Bay and Steiner)	,,
F 658.—**2 K.V.A. Transformer** for exciting the above tube. Input 110 v. (or 220 v.) single phase alternating current. Output 4000 volts with a current of 0·5 amps. Frequency 50 Herz.	,,
F 659.—**Regulating Sliding Resistance.** 9 amp., 11 ohm. ...	,,

ABSORPTION TUBES.

H 256.—2 **Quickly Detachable Tubes,** with screw end caps and quartz end plates. Length of liquid, 5 mm.	£5 10 0
H 257.—2 ditto. ditto. Length of liquid, 10 mm. ...	4 10 0
H 258.—2 ditto. ditto. Length of liquid, 20 mm. ...	4 10 0
H 260.—**Micrometer Adjustable Tube** reading from 0 to 5 mm. thickness of liquid stratum. With quickly detachable mount	17 0 0

BATTERIES.

F 692.—**Oldham type H.T.L. Secondary Battery,** 120 volts, total 240 volts	8 4 0

PHOTOMETER.

The photo-electric photometer is based on a modification of a system described by von Halban in *Zeits. f. Phys. Chem.*, 42, pp. 321-58, 1924. A small part of the beam of light emerging from a monochromator is reflected into a photo-cell by a quartz plate, while the rest of the beam passes through the substance whose absorption is to be measured (contained in a tube with quartz windows), through a revolving sector (fully open) and then into a second photo-cell. The two cells deliver currents of opposite sign into an electrometer, and the potentials on the cells are so adjusted that the electrometer shows no deflection. A comparison tube is then substituted for the tube containing the solution and the currents in the two cells are then restored to equality by adjusting the opening of the revolving sector. The difference between the transmission of the sector when so adjusted and its transmission when fully open is the same as that between the transmission of the comparison tube and of the absorption tube, and is thus a satisfactory measure of the absorption of the substance for the wavelength of the light provided by the monochromator.

The sector is adjustable while it is running. The criticism is sometimes made that the calibration of such sectors is liable to become unreliable owing to wear. In order to avoid this the transmission of the sector is separately measured by means of a vacuum photo-electric cell and galvanometer.

The two absorption cells, which are of the quickly detachable type described on page 16, are carried on a sliding mount whose position can be altered from outside the photometer and is determined by stops limiting its range of movement.

The photo-electric photometer is contained in a light tight box, in which are the optical system (except the monochromator), the sector, the absorption tubes, the photo-electric cells, a Lindemann Electrometer with microscope for viewing it, and the complete photo-electric circuit. External connections are made to the batteries, and to the galvanometer which measures the current in the vacuum photo-cell indicating the opening of the rotating sector disc. *Price on application.*

MONOCHROMATIC ILLUMINATING SYSTEM.

It is particularly important in ultra-violet absorption work with photo-electric cells that the monochromator should deliver pure monochromatic light. If an ordinary monochromator is used alone it is possible to introduce very considerable errors due to the scattered light within the instrument. Therefore, two monochromators should be used in series, the slit of the second instrument being placed at the focus of the telescope of the first one. In this way, any impurity present in the supposedly monochromatic light produced by the first instrument is dispersed by the second and a very small amount of impurity finally emerges from the second instrument. It is not, however, necessary that the first monochromator should be an extremely precise instrument, and we have designed a special simple spectrometer for this purpose. This is the instrument referred to as the preliminary dispersing instrument in the outfit described.

Preliminary Dispersing Instrument. *Price on application.*

The second monochromator is our standard, **Monochromatic Illuminator for the Ultra-Violet and Visible, reading from 1850a to 9000a direct in wavelengths** shown in Fig. D 33 page 30.

The quartz lenses are of 31 mm. aperture and 210 mm. focal length for 3000A. They are figured by the Hilger Interferometers for the removal of spherical aberration.

The beam of light from the collimator passes at minimum angle through a cornu prism of quartz (height 32 mm., length of face 42 mm.), and is then reflected from a plane mirror into the telescope. The mirror consists of a plane parallel plate of quartz coated on the back with mercury tinfoil amalgam, which is an excellent reflector in the ultra-violet. The prism and mirror stand on a table which is rotated by means of a fine steel screw in the same way as the prism table of the wavelength spectrometer, constant deviation type, the wavelength of the portion of the spectrum under observation being read off directly on a helical drum. The average accuracy of reading throughout the range is about 3 A. The telescope and collimator are each provided with a scale, engraved in wavelengths, for setting the focus of the lenses for the part of the spectrum under observation.

The improved symmetrical slits supplied on these instruments are shown in Figs. D 33a and D 33b.

Slit D 33a, for the collimator, is provided with a screw-thread T in front of the slit, into which is screwed a diaphragm of 11 mm. aperture. If it be desired to utilise the entire length of the slit this diaphragm can be removed. The screw-thread forms a ready means of adapting an eyepiece to the slit, an arrangement which is often convenient.

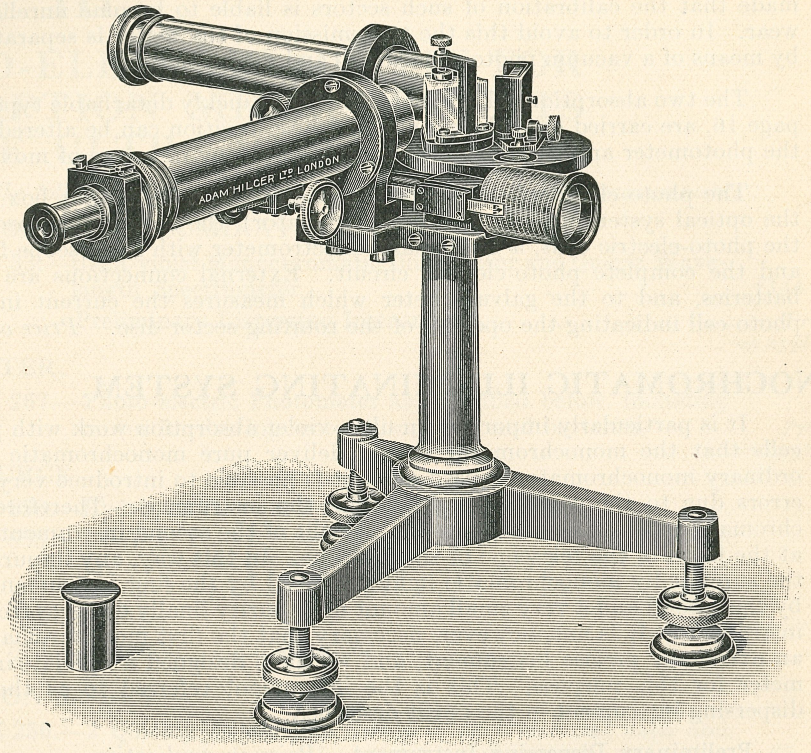

Fig. D 33

Slit D 33b for the telescope differs from slit D 33a only in having a block B with recess R for thermopile, and an eyepiece for observation of the slit and thermopile. This block is no hindrance to the use of the slit for the monochromatic illuminator.

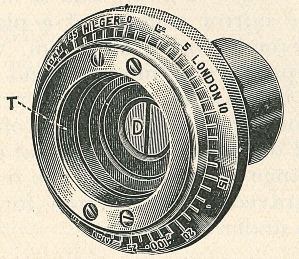

Fig. D 33a

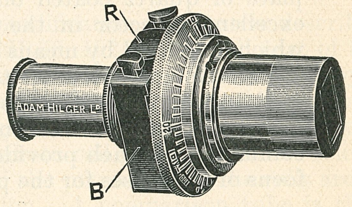

Fig. D 33b

Both the above slits are adjustable by large milled ring, with division reading to 1-1000 inch.

D 33.—Quartz Wavelength Spectrometer and Ultra-Violet Monochromator	£144 18 0

LIGHT SOURCE.

We recommend the hydrogen tube as the source of light as this gives a continuous spectrum in the ultra-violet, but it is also possible to use an arc instead. A spark is not suitable. The K.B.B. Quartz Mercury Vapour Lamp is also a possible alternative, though the number of lines given in its spectrum is insufficient for some purposes.

The Hydrogen Tube recommended is fully described, together with the necessary exciting equipment on pages 17-18 of this booklet.

ABSORPTION TUBES.

The quickly detachable absorption Tubes are exactly similar to those listed for use with the Hilger Spekker Ultra-Violet Photometer and described on page 16.

BATTERIES.

The entire potential supply for the photo-electric cells is derived from a high tension secondary battery giving 240 volts. For this purpose we use and recommend " Oldham " type H.T.L. batteries. Two 120 volt batteries are used. These consist of the requisite number of 10 volt blocks of glass cells, of 2750 milliampere hours capacity, held in well made wooden carrying crates with bases and lids.

F 692.—120 volt H.T. Accumulator, type H.T.L., 3 tier	£4 2 0

CORRIGENDUM.

The price of *The Practice of Absorption Spectrophotometry* is **5s. 0d.** nett; **5s. 3d.** post free.

Page 32. ADAM HILGER, LTD.

M.1000/12/31. B3020.

APPENDIX A.

PUBLICATIONS.

Of interest in connection with Absorption Spectrophotometry.

"The Practice of Absorption Spectrophotometry with Hilger Instruments." Gives particulars of the applications of spectrophotometry to chemical, biological and other problems. Together with much new matter it contains the substance of the following booklets. It gives accounts of the methods to be adopted in the use of certain recommended types of instrument. Price 3s. 6d. *nett*; 3s. 8d. *post free.*

"Absorption Spectra and Spectrophotometry" *post free.* An introduction to the applications of Absorption Spectrophotometry.

"Absorption Spectrography and Some of its Applications to Chemistry." By F. Twyman, F.Inst.P., F.R.S. A simple resumé of the principal methods now in use. Reprinted from the *J.S.C.I* vol. XLIX. Price 1s. 0d. *post free.*

"A Supplement to the Bibliography of Recent Work on Absorption Spectrography" *post free.*

"The Detection and Investigation of Poisons by Spectroscopy" *post free.*

"Spectroscopy in Control of Purity in Food Stuffs" *post free.*

"Biological Applications of Absorption Spectrophotometry" *post free.*

"A Review of Present Knowledge on Absorption Spectrophotometry as related to Vitamin D and Allied Substances" *post free.*

"Recent Applications of Absorption Spectrophotometry," a bibliography containing the substance of the following booklets together with extensive additions. (*To be published shortly*).

"Recent Work on Absorption Spectrography," a bibliography selected by Dr. Wallace R. Brode (1928) *post free.*

APPENDIX B.

THE DETECTION BY SPECTRUM ANALYSIS OF METALS IN PLANT AND ANIMAL FIBRES AND OTHER ORGANIC SUBSTANCES.

A type of problem which is most readily approached by means of spectrum analysis is the detection and identification in organic substances of small quantities of metals which may be included fortuitously or whose presence may have important bearing on a chain of circumstances. Such problems are: tracing the effect on assimilation or plant growth of the presence or absence of certain metals; ascertaining the cause of stains on textiles, etc.

The metals concerned are usually present in such small quantities as to be exceedingly difficult of detection by ordinary analytical means and it is for such cases that the methods of emission spectrum analysis are very advantageous. A very brief account of such work, accompanied by some bibliographical references will be found in the booklet "The Practice of Absorption Spectrophotometry" (Adam Hilger Ltd.) while the ordinary technique of emission spectrum analysis is fully dealt with in "The Practice of Spectrum Analysis (Adam Hilger Ltd.).

But few additions to the apparatus described on p. 8 are required to suit it for this work; the following includes everything that is necessary:

ADDITIONAL ACCESSORIES FOR DETERMINING METALLIC CONSTITUENTS BY EMISSION SPECTROGRAPHY.[*]

Catalogue No.		"Outfits for Metallurgical Analysis." 4th Edn. Page.	Price.
F 15.	—**Quartz Sphero-cylindrical Condenser** on raising and lowering stand	15	£6 5 0
F 127.	—**H.S. Copper Electrodes,** 1-dozen pairs ...	19	1 5 0
F 623.	—**H.S. Graphite Electrodes,** 1-dozen pairs ...	19	1 16 0
F 403.	—**H.S. Pure Silver Electrodes,** 1 pair, with one piece each of F 404 H.S. silver foil and F 405 H.S. silver wire	19	3 17 6
	Note.—The silver electrodes are necessary where it is desired to detect extremely minute traces of copper in plant or animal fibre.		
F 140.	—**1-doz. Ilford Special Rapid Panchromatic Plates** 10″ × 4″	23	0 13 9
	Note.—These are desirable for showing up with greater sensitiveness such elements as lithium and sodium.		
F 146.	—**Wavelength Tables for Spectrum Analysis,** second edition, Twyman and Smith ...	24	0 14 6
F 304.	—**Enlarged Spectrum of Copper Arc,** marked in wavelengths, in three sections	26	1 10 6
H 217.	—**Eyepiece with fine scale**: a useful accessory not only for general observation, but for measuring the separation of unknown from known lines for determining the wavelengths of the former	32	2 10 0
	Note.—This eyepiece is identical with that quoted under the Absorption Outfit, except for the addition of the scale, and if the H 217 is purchased it is not necessary to purchase the former.		

These supplementary items are not further described in this booklet. Reference should be made to our publication "Spectrographic Outfits for Metallurgical Analysis," which will be sent post free on application.

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[*] For the methods of spectrum analysis by emission spectrography see "The Practice of Spectrum Analysis," Adam Hilger, Ltd., 5th Edition, 1931, p. 52, price 3s. 6d.; *post free* 3s. 8d.

APPENDIX C.

ABBREVIATED LISTS OF PURCHASERS OF HILGER SPECTROPHOTOMETERS.

ULTRA-VIOLET SPECTROPHOTOMETERS.

List of some of the laboratories to which we have supplied our Photometers for the Ultra-violet.

INDUSTRIAL AND OTHER RESEARCH LABORATORIES

Government Laboratory, London.
Lister Institute, Experimental Pathological Department.
Cancer Hospital (Free), London, S.W.
British Humane Association, London.
Dr. S. Judd Lewis, F.I.C., London.
Kodak Limited, Wealdstone.
Col. G. Sims Woodhead.
Royal Airship Works, Bedfordshire.
Messrs. Chance Bros. & Co., Ltd., Smethwick.
The British Thomson-Houston Company, Ltd., Rugby.
J. Bibby & Sons, Ltd., Liverpool.
Glasgow Royal Cancer Hospital.
Imperial Chemical Industries Ltd., Stevenston.
Pilkington Bros., Ltd., St. Helens, Lancs.
L'O.R.S.C.T., Puteaux, France.
M. Victor Henri, Paris.
Les Manufactures des Glaces de St. Gobain, Paris.
S. A. Lignes Télégraphiques et Téléphoniques, Conflans Ste. Honorine.
Societe Anonyme Française Holophane, Paris.
M. A. de la Bruère, Nantes.
Institut de Chimie, Lyon.
L'Union Chimique Belge, Brussels.
R. Navy Yard, Spezia.
Italian Air Ministry.
Harriman Research Laboratories, New York.
Messrs. Eastman Kodak Co., Rochester, New York.
Beth Israel Hospital, New York.
Rockefeller Institute for Medical Research, New York (2 instruments).
Royal Baking Powder Co., New York.
Jewish Hospital of Brooklyn, New York.
State Institute for Study of Malignant Diseases, Buffalo, New York.
Mead-Johnson Co., Evansville, Indiania
Mr. Samuel O. Hoffman, San Francisco.
Carnegie Institute of Washington, Coastal Laboratory, Carmel, Cal.
Imperial Japanese Navy.
Imperial Japanese Army.
Japanese Military Aeronautical Service.
Iwaki Glass Works, Japan.
Electric Bureau of Tokyo Municipality.
Sumitomo Copper Works, Osaka.
D. Tadokoro, Tokyo.
South Manchurian Railroad, Dairen.

UNIVERSITIES.

London—
  University College, Chemical Laboratory (2 *Instruments*).
  King's College, Chemical Laboratory.
Cambridge—
  Bio-Chemical Laboratory.
  Chemical Laboratory.
Oxford—
  The Laboratory, Magdalen College.
Bristol—
  Chemistry Department.
Leeds—
  Organic Chemistry Department.
Liverpool—
  Chemical Laboratory (3 *Instruments*).
  Muspratt Laboratory.
Manchester—
  Chemical Laboratory.
Glasgow—
  Physical Chemical Laboratory.
Belfast—
  Queen's University, Chemical Laboratory.
Lyon—
  Laboratoire de Chimie Organique et Toxicologie.
Louvain—
  Laboratory of General Chemistry.
Brussels—
  Laboratory of General Chemistry.
Ghent—
  Laboratory of General Chemistry.
  Toxicological Laboratory.
Liège—
  Chemical Laboratory.
Basle—
  Physikalisches Institut.
  Mineralog-Petrographische Anstalt.
Cracow—
  Medical Chemistry Laboratory.
Dacca—
  Physical Laboratory.
Columbia, New York—
  New Medical Centre.
Cornell—
  Chemistry Laboratory.
Ohio—
  Department of Physics.
California—
  Department of Chemistry.
Chicago—
  Department of Chemistry.
Pittsburgh—
  Department of Physics.
Johns Hopkins.
Colorado.
British Columbia—
  Physics Department.
Buenos Aires—
  Physical Laboratory.
La Plata—
  Faculty of Physico-Mathematical Science.
Cape Town—
  Chemistry Department (2 *Instruments*).
Kyoto—
  Physical Laboratory.
Kyushu—
  Physical Department.
Hokkaido—
  Physical Laboratory.

OTHER EDUCATIONAL ESTABLISHMENTS.

London Hospital Medical School, Department of Physiology.
Milan Polytechnic, Chemical Industrial Institute.
Polytechnic Institute, Laboratory of Physical Chemistry, Leningrad.
Iowa State College, Physics Department.
Medical College, Calcutta, Biochemical Research, Chemical Examiner's Department.

VISUAL SPECTROPHOTOMETERS.

A list of some of the laboratories to whom we have supplied our Nutting Photometers, both of the Industrial and Research Type and earlier models.

INDUSTRIAL AND OTHER RESEARCH LABORATORIES

- Admiralty—
  - R.N. Cordite Factory.
  - Portsmouth Dockyard (2 *Instruments*).
  - Department of Scientific Research and Experiment.
  - The Experimental Station, Porton, near Salisbury.
- The Government Laboratory, London.
- National Physical Laboratory.
- National Institute for Medical Research, London.
- Department of Scientific and Industrial Research—
  - Building Research Station, Garston, Watford.
- Ilford Ltd., London.
- Imperial Dry Plate Co., Ltd., London.
- Osram Lamp Works, London.
- South Metropolitan Gas Company, London.
- Lawes Agricultural Trust—
  - Rothamsted Experimental Station, Harpenden.
- British Dyes, Ltd.
- Chance Bros. and Co., Ltd., Birmingham.
- Kosmos Photographics Ltd., Letchworth.
- W. Forster Brown, Esq.
- J. A. Jobling & Co., Ltd., Sunderland.
- R. Stazione Bacologica Sperimentale, Padova.
- Officine Galileo, Florence (2 *Instruments*).
- Laboratorio di Precisione, Rome.
- Dr. Giuseppe Bastianelli, Rome.
- Chemical Agricultural Laboratory of Portici, Naples
- Philips Glowlampworks, Eindhoven.
- Bureau of Standards, Department of Commerce, Washington, D.C.
- Department of Agriculture, Bureau of Chemistry, Washington, D.C.
- Naval Research Laboratory, Bellevue, Anacostia.
- Eastman Kodak Co., Rochester, N.Y.
- American Optical Co., Southbridge, Mass.
- E. I. du Pont de Nemours.
- Electrical Testing Laboratories, New York.
- Imperial Department of Agriculture in India.
- Institut National de Physique, Shanghai.
- Imperial Japanese Navy (2 *Instruments*).
- Institute of Physical and Chemical Research, Tokyo—Wada Research Laboratory.
- Tokyo Dry Plate Co.
- Army Aviation Main Supply Station, Tokorozawa Branch, Saitama-Ken.
- Tokyo Industrial Experimental Station (2 *Instruments*).
- Electric Bureau of Tokyo Municipality.
- Taihoku Central Institute of Researches.
- Sumitomo Densen K.K., Osaka.
- Taiwan Sotokufu, Taihoku, Formosa.
- Government Department of Communications, Teishinsho.

UNIVERSITIES

- London—
  - University College—
    - Chemistry Department.
  - King's College—
    - Physics Department.
    - Chemistry Department.
  - Imperial College of Science and Technology.
- Cambridge—
  - Chemical Laboratory.
- Bristol—
  - Physical-Chemistry Department.
- Liverpool—
  - Muspratt Laboratory.
- Manchester—
  - Chemical Laboratory.
- Aberdeen—
  - Materia Medica Department.
- Glasgow—
  - Natural Philosophy Department.
- Wales—
  - University College, Swansea.
  - University College of South Wales and Monmouthshire—
  - National College of Medicine, Cardiff.
- Brussels—
  - Service de Chimie Générale.
- Liège—
  - Laboratoire de Chimie Générale.
- Copenhagen—
  - The Chemical Laboratory.
- Oslo—
  - Chemical Laboratory.
- Lisbon—
  - Chemical Laboratory.
- Naples—
  - Department of Pharmaceutical Chemistry.
- Cornell.
- Wisconsin.
- Harvard (2 *Instruments*)—
  - Chemical Laboratory.
  - Medical School, Dept. of Physical Chemistry.
- Indiana.
- Clark University, Worcester, Mass.
- Michigan.
- Toronto—
  - Physics Department.
- Université de Laval, Quebec.
- La Plata—
  - Faculty of Physico-Mathematical Science.
  - Institute of Physics.
- Allahabad—
  - Chemistry Department.
- Tokyo—
  - Chemical Institute.
  - Aeronautical Institute.
  - College of Engineering, Department of Applied Chemistry.
  - Medical Department.
  - Applied Science Department.
- Tohoku.
- Kyoto—
  - Physics Department.
- Kyushu Imperial University (3 *Instruments*)—
  - Department of Medical Jurisprudence.
  - Chemistry Department.

OTHER EDUCATIONAL INSTITUTIONS

- Polytechnic Institute, Copenhagen, Physical Chemistry Laboratory.
- R. Scuola Politecnica, Instituto di Elettrochimica, Naples.
- William M. Rice Institute, Houston, Texas.
- Lafayette College, Easton, Pa.
- California Institute of Technology, Pasadena.

Other Educational Institutions—*continued*

Wellesley College, Wellesley, Mass.
Transvaal University College, Pretoria.
Victoria College of Science, Nagpur.
University College of Science, Calcutta.
Dacca College, India.
Royal Institute of Science, Bombay.
Peking Union Medical College, Peking.
Higher Technical School, Tokyo, Applied Science Department.
Yokohama Higher Technical School, Applied Science Department.
Kanazawa Medical College, Ohsuto Medical Department.
Hamamatsu Higher Technical School.

In addition to the foregoing we have supplied many of the *Hüfner type of Spectrophotometer* to investigators and laboratories including :

Industrial and other Research Laboratories

Kodak Ltd., London.
Brifco Ltd., London.
The Natural Colour Kinematograph Co., Ltd., London.
Huebner-Bleistein Patents Co., U.S.A.
Eastman Kodak Co., Rochester N.Y. (2 *instruments*).
Ansco Co. Binghampton, N.Y.

Universities and other Educational Institutions.

London University.
    University College.
    Goldsmith's College.
Minnesota University, Minneapolis.
Imperial University Tokyo, Science College.
Technische Hoogeschool, Delft, Holland.

November 1931.

ADAM HILGER, LTD.,
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Cable Code—Western Union.
Cable Address—" Sphericity, London."

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